MARCH 1956

THE WELDING JOURNAL

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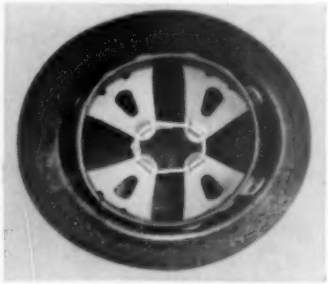

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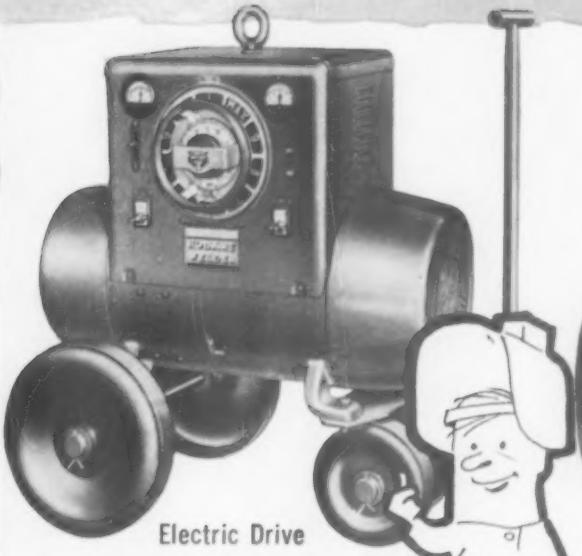

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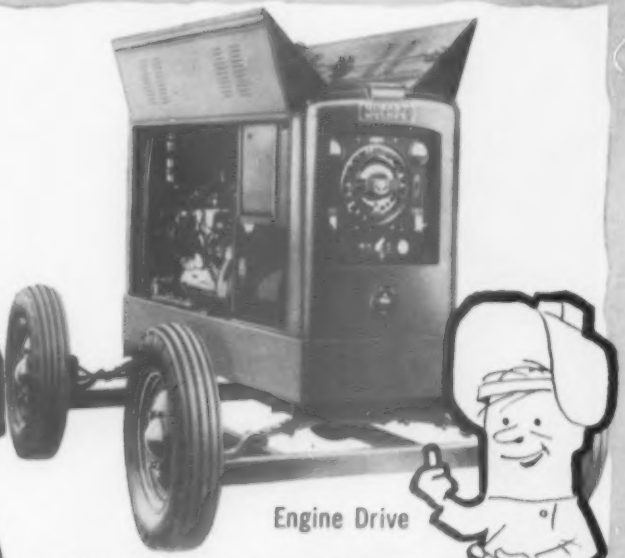

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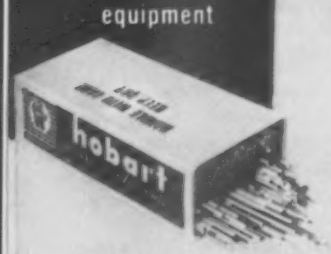

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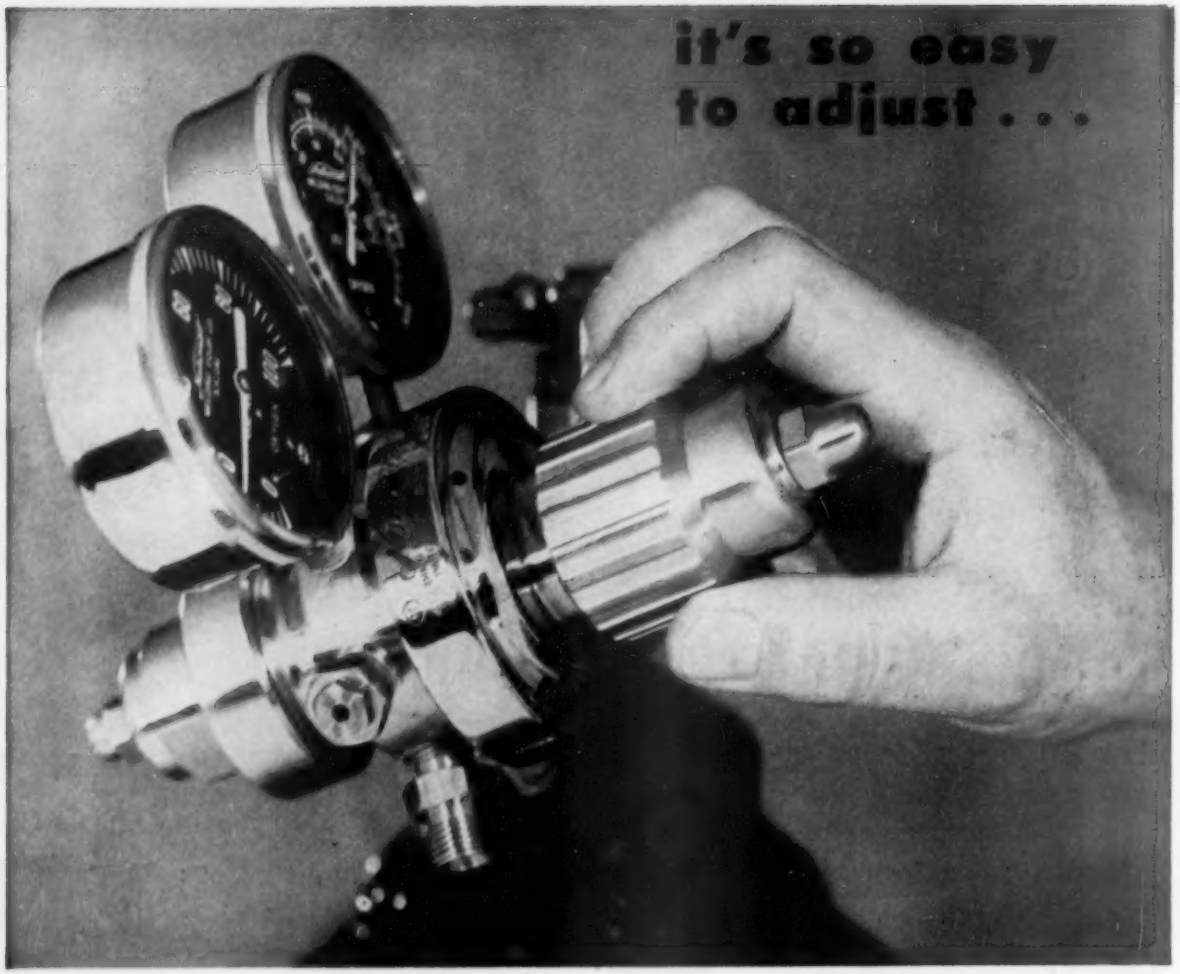

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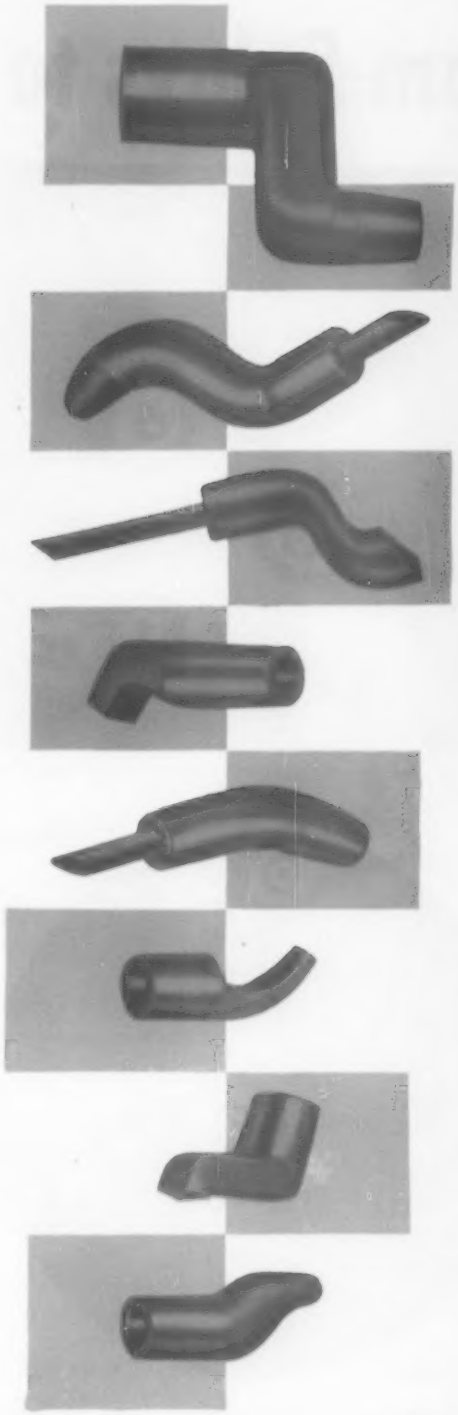

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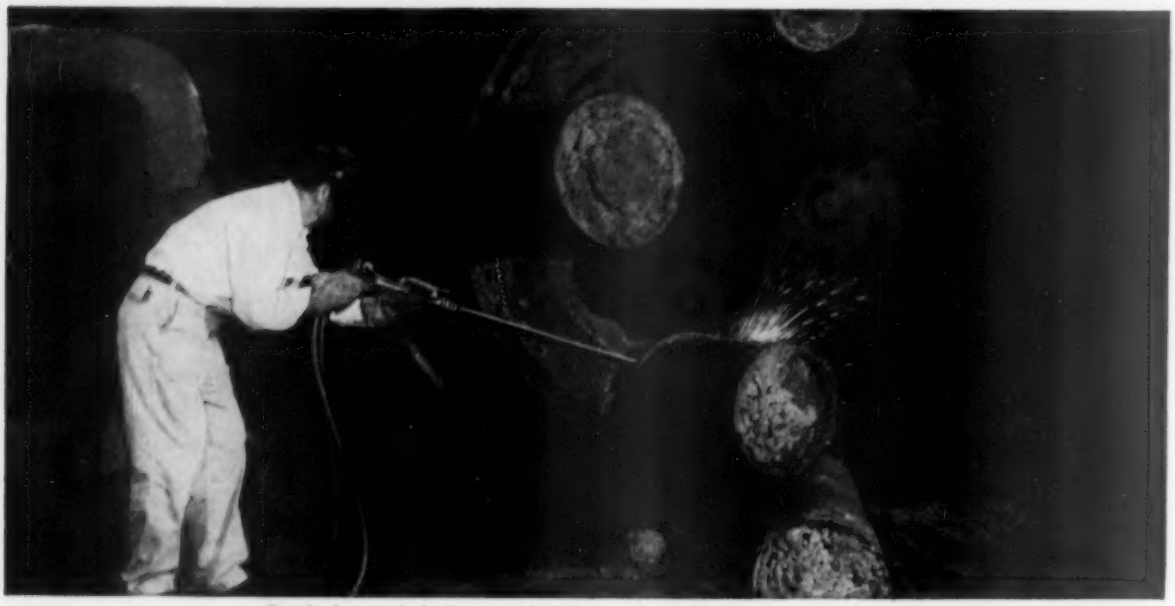

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EDITORIAL

REAPPRAISING WELD JOINT FACTORS

In the early days of welding, particularly with bare electrodes, weld-test specimens frequently failed in the weld metal. Too often the weld metal did not develop the full properties of the base metal. In recognition of this condition, construction codes assigned a reduction factor to joints in welded construction.

Code writers borrowed the term, joint efficiency, from riveted construction as a designation for this joint reduction factor. The ASME Boiler Construction Code assigned a value of 0.90 for the joint factor for welds whose soundness had been proved by radiography, and 0.80 for welds not subjected to inspection by radiography.

During the quarter of a century since these values were assigned, there has been marked improvement in the quality of welding. Covered electrodes have replaced bare wire. Welding techniques have constantly been improved, along with an increase in our knowledge of the metallurgy of the welding process. The time is ripe to recognize these improvements.

In assessing the value to be placed on the joint, attention has been focused on possible imperfections in the weld metal. The laminations, inclusions, and segregation in the base metal have been pushed into the background. As a result, the weld has suffered by comparison.

The evidence of research and experience is that welds whose soundness has been assured by radiographic examination are, by and large, as good as the plate in which they are made. Such welds should be given the same credit as the plate, namely, a joint factor of unity. Joints which receive a lesser degree of inspection than full radiography should, of course, be given a joint factor of less than unity.

The ASME Boiler and Pressure Vessel Committee has had this matter under study for the past two or three years. The recommendations of the Special Task Group will soon be ready for action by the Main Code Committee. Thus, a long-needed reappraisal of weld reliability may be expected in the near future.

Elmer O. Bergman
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The mark made by a TEMPILSTIK° may gradually change in color as heating progresses. The change in color, or in color intensity, is never to be interpreted as a temperature indication. The TEMPILSTIK° mark melts when its temperature rating is reached and only this change from the dry to the liquid condition is the significant temperature signal.

In some applications this simple method may not suffice because evaporation of the TEMPILSTIK° mark on prolonged heating, or its gradual absorption by the surface at high temperatures, may leave too little residual substance for unambiguous observation. In such cases stroking or touching the work-piece with the TEMPILSTIK° at regular intervals during the heating process is recommended. The TEMPILSTIK° will leave a dry mark at temperatures below its rating and a liquid streak when its temperature rating has been reached or exceeded. If the workpiece is not accessible for applying a TEMPILSTIK° during the heating process, then TEMPILAQ°, or possibly TEMPIL° PELLETS, should be used instead.

TEMPILSTIKS° will usually glide over unheated polished surfaces (like glass, polished stainless steel, etc.) without leaving an appreciable mark. Therefore, in applications that involve smooth or polished surfaces TEMPILSTIKS° should be used by touching or stroking the workpiece periodically during the heating process, as previously described, because a liquid streak will be made on contact as soon as the specified temperature is reached. Where it is necessary to mark a smooth work piece surface prior to heating, TEMPILAQ° should be used.

A hot radiating surface will appear relatively dark under intense illumination from an external source, and this fact can be utilized to improve recognition of the temperature signal against a red-hot background. The use of TEMPIL° PELLETS or TEMPILAQ° instead of TEMPILSTIKS° will further improve visibility under these conditions.

On rapidly moving objects, like magnesium or aluminum sheet during spinning operations, it is impossible to see whether the applied TEMPILSTIK° leaves a dry or melted mark. However, with a little experience operators quickly learn to sense the smooth gliding of a TEMPILSTIK° over a surface which is hot enough to melt it on contact, as contrasted to the frictional drag on a cooler surface. If the top of the TEMPILSTIK° is brought in contact with the moving metal surface for a brief moment at a time, and with light pressure only, the heat contribution of friction is trivial enough to be ignored.

The above described "sensing technique" may also be employed on hot radiating surfaces where the bright background makes it difficult to distinguish whether or not the TEMPILSTIK° mark had melted.

An appropriate series of TEMPILSTIK° marks, applied to the workpiece or surface under investigation before heating begins, will provide a record of the maximum temperature attained during a process or operation. Subsequent examination will show that all TEMPILSTIK° marks up to a certain temperature rating had melted, while those of a higher rating had not. The maximum attained temperature must consequently lie somewhere in the interval between the highest melted and the lowest unmelted TEMPILSTIK° rating.

The temperature distribution and isothermal boundaries of surfaces such as furnace walls, melting ladles, cement kilns, etc., can be established by using an appropriately chosen series of TEMPILSTIKS° to draw a pattern of lines (parallel, concentric, radial, etc.) on the area under investigation. The heat conduction along a surface can be effectively studied by the progressive melting of suitably chosen TEMPILSTIK° lines. Caution must be exercised not to permit the mark made with one TEMPILSTIK° rating to cross or overlap the mark of a dissimilar TEMPILSTIK°, as such a mixing of different TEMPILSTIK° marks would destroy their accuracy.

TEMPIL° products will give good results in induction heating and in ionized air, as well as in the presence of static electricity about electrical equipment, where electrical means of measuring temperatures often function erratically.

1955 ADAMS LECTURE

AN INTERPRETATION OF RESEARCH AND EXPERIENCE IN STRUCTURAL WELDING

Particular reference to the brittle fracture problem is made in the American Welding Society's honor lecture presented at National Fall Meeting in Philadelphia on October 17, 1955

BY LA MOTTE GROVER

LA MOTTE GROVER, a welding engineer, has been associated with Air Reduction Sales Co. during the last 16 years, assisting fabricators, engineers, designers, railroads and shipbuilders in applications of arc welding and the oxyacetylene processes, and in writing specifications for materials, design practices and construction procedures.

He is the author of a Manual of Design for Arc Welded Steel Structures and various technical papers on design, research, construction methods and procedures for welded bridges, buildings, and structural parts of ships, some of which have been published in foreign countries as well as in the United States.

Prior to joining Air Reduction, he served a number of years as Bridge Engineer of the State Highway Commission of Kansas; was at one time with the Missouri Pacific Railroad, and was an assistant professor of applied mechanics at Kansas State College. He was closely affiliated during World War II with the control of welding in the shipbuilding industry, serving upon advisory committees of the American Bureau of Shipping and the U. S. Maritime Commission. He is Chairman of the Structural Steel Research Committee and the Fatigue Testing Committee of the Welding Research Council.

SYNOPSIS. The results of experience with large welded structures have been supplemented by tests of realistic prototypes of structural members, to provide a basis for designing and building safe, economical welded engineering structures.

Research and experience have demonstrated similarities between welded and riveted structures with respect to factors affecting the initiation and propagation of brittle fracture. They have also pin-pointed the significant differences between these two types of construction in this respect. This facilitates correlation of test results with the behavior of both welded and riveted structures, drawing upon many years of experience with both methods of construction.

The excellent service records of a good many welded bridges serving in very cold climates indicate that the "nil ductility temperature" of the steel material, as determined by drop-weight and explosion crack-starter tests, pegs the lowest safe operating temperature at an unduly conservative figure for bridges.

New structural steel materials now available assure better uniformity of notch toughness at a reasonable cost, and provide an even greater margin of safety.

The effects of the various fabrication operations upon the ductile behavior of engineering structures have been studied and are now quite well understood. This provides a sound basis for control of fabricating operations.

Results of experience, as well as more fundamental information from research, facilitate an evaluation of details of design, to determine the degree of refinement required, to provide safe structures without resorting to costly impracticable arrangements and details.

Modifications are being made in the AMERICAN WELDING SOCIETY's bridge specifications to provide more rational requirements for suitable welding procedures.

With the provision of one of the newer quite inexpensive structural steel materials, reasonable care in designing and in adhering to construction specifications is relied upon to provide an increased margin of safety for welded bridges, ships, and other large engineering structures. Experience, together with the results of tests of structural members, indicates that this solution should be effective and adequate.

Introduction

I have wished that I might find an especially suitable and less trite manner of expressing my deeply felt appreciation for the privilege that has been accorded me, to present the Thirteenth Adams Lecture, in honor of the "grand old man of welding," the Founder of the AMERICAN WELDING SOCIETY and the Welding Research Council, Dr. Comfort A. Adams. I am sure that my feeling is deeper for having known him for a good many years and having respected his philosophy and opinions.

I recall a story that Dr. Adams once told, to illustrate one of the cardinal principles of his philosophy in applying scientific knowledge and the findings from research.

It was about a young doctor of philosophy, fresh from a college of engineering, who was given a rather involved practical problem to solve. Then his solution was tried in practice. It failed miserably. The ready explanation offered by his boss was, "He's just like all these young college graduates. He's just too theoretical."

Dr. Adams observed, "No, he's not too theoretical; he just used the wrong theory."

From this story I have taken the theme for this lecture—a discussion of some of the things we have learned from research and experience in matters related to welded steel structures, and how it seems to me they can be applied appropriately to the solution of problems that arise in designing and building welded structures.

Structural welding has had its growing pains, just as other methods of construction have had theirs. Difficulties with any method may arise and prevail for a time. Sometimes they recur when changes are made in materials or methods—for example, the unforeseen reactions that still occur now and then between certain aggregates and portland cement materials and result in permanent expansion or growth of concrete.

In such cases, the engineering profession becomes apprehensive and doubtful for a while. Then, from all outward appearances, the troubles are cleared up rather suddenly in an apparently simple manner. However simple the methods of correction may seem, their discovery through research and study has usually been anything but simple. They may involve details of design and construction practices, but very often it is the improvement and better control over materials that proves to be the major factor.

Apart from non-structural factors such as corrosion, there are five rather well recognized possible causes of failure, serious structural damage or limited usefulness of engineering structures such as steel bridges, ships, building frames, railway car underframes, heavy construction equipment, and similar fabricated steel construction:

1. Instability or buckling of compression members or elements.
2. Excessive elastic deflections.
3. Fatigue (stress repeated many times).
4. Plastic deformations of such a character or degree as to result in a serious impairment of the usefulness of a structure.
5. Brittle fracture.

Contrary to conventional design assumptions, the attainment of a localized yield point stress does not, in itself, constitute a significant impairment of the strength of a structure. In any practical engineering structure there are inevitably a good many points of comparatively high concentrations of stress; and localized plastic strains occur under the first applications of normal design loading. They are the result of the geometric shape of almost any kind of useful members and their connections, and of unavoidable imperfections in fabrication and erection, and in conventional methods of design. It is important to differentiate between these localized yield point stresses and comparatively widespread fields of yield point stress.

These localized concentrations of stress and strain are not recognized in conventional analysis and design by the elastic theory. Even in the newer plastic theory of analysis and balanced design of continuous frame structures, and in the evaluation of the effect of secondary stresses, it is only the less highly localized plastic strains at certain locations that are recognized.

Research at Lehigh University into the plastic behavior of large structural steel members and rigid connections has contributed a great deal of valuable information toward the practical use of the plastic theory of design. Their tests have included tests to destruction of corner connections or "knees" involving sections as large as 36 inch deep, wide-flange beams, as well as tests of complete rigid frame bents.[1]

The limitations of this method of design have been investigated. The possibility of fracture has been studied, as well as instability or buckling of compression members or elements, and excessive deflections or deformations. Rules of design and application have been formulated to assure plastic behavior, as assumed, and

to preclude structural damage or excessive deformations or deflections.

In the advanced stages of loading of continuous frames designed by this method, plastic "hinges" occur, successively, at the various locations of maximum bending stress, thus redistributing bending moments to other less highly stressed portions of the structure. The result of applying the method is a balanced design in which each member or structural part has, as nearly as possible, the same useful strength as any other member or part—that is, the maximum useful moment capacity of each member is utilized. The material is therefore used efficiently. The resulting design is based upon the true ability to carry load. Only by the use of welding can the economic benefits of this method be fully realized.

Thousands of tons of steel are wasted every year in designing steel building frames by the conventional elastic theory, because it results in some members or their parts being over designed, as compared with other parts of the same structure, with respect to their true ultimate carrying capacity.

Studies and test results indicate that the strains accompanying the formation of the plastic hinges, in usual cases, do not exceed 1.5%; so no appreciable strain hardening or serious loss of ductility would be expected, unless there are severe notch-like-details or defects in the affected area.

This work has been carried out under the general guidance of the Structural Steel Committee of the Welding Research Council. It was started under the direct supervision of Professor Bruce Johnston who later joined the staff of the University of Michigan, and was succeeded in this work by Professor Lynn S. Beedle at Lehigh University.

In general, all of the practical engineering methods of design have been quite satisfactory for providing safe structures, when applied in a rational manner based upon a good understanding of the behavior of materials. The structural steel material used in such structures usually has retained enough true ductility or notch toughness, after undergoing the various operations of fabrication and erection, to accommodate itself to the actual conditions imposed in service.

In various research and study projects, the Structural Steel Committee of the Welding Research Council and its Fatigue Testing Committee have investigated a number of the factors that have been mentioned as possible causes for serious structural damage. Their tests have all been of specimens that simulate actual structural members or their parts. These specimens have been simple from an engineering viewpoint, although complex from the viewpoint of the scientist who is studying fundamentals.

The objectives have been to develop the kind of engineering information that can be applied in practical design and control of materials and construction, and in writing some of the codes, specifications, manuals and handbooks of the American Welding Society covering recommended practices in structural welding.

The results of some of these testing programs afford a good deal of information that can be used for correlation with fundamental information developed through the use of less complex specimens, for example, in studying the problem of brittle fracture.

They are especially useful in this respect because there have been comparatively few service fractures or serious difficulties in actual welded structures such as bridges, constructed of American structural steel. Consequently, there is a dearth of information for use in correlation, based upon adverse service conditions.

The Brittle Fracture Problem

The discussion of brittle fracture in this paper will be limited for the most part to an attempt to correlate research findings with experience, in such a manner as to be of special interest to bridge and structural engineers.

Most of the intensive studies of the brittle fracture problem, made since the early part of 1943, have been associated largely with investigations of ship failures or the behavior of military weldments, and more recently the behavior of pressure vessels and tanks. However, the problem is an old one. Most of its general fundamental aspects have been recognized for many years, even before bridge engineers in Germany and Belgium encountered similar difficulties in 1937 and 1938.

In a critical survey by Shank of brittle fracture in carbon steel structures other than ships,[2] information was found on such failures that occurred as long ago as 1879. One of his most interesting conclusions was that "there is no evidence available to demonstrate that the percentage incidence of brittle failure in non-ship structures has either increased or decreased with the advent of welding."

The general basic factors involved in this problem have long been recognized as:

1. Notch ductility or toughness characteristics of the materials.
2. Service temperatures.
3. Localized state of stress as influenced by geometric shape and proportions, as well as loading.
4. Localized rates of application of stress.

By taking extreme precautions in connection with only one of these factors, an engineer might preclude brittle fracture, but this would not be a practical solution. For example, one might specify a special low carbon, quenched and tempered alloy steel, or some other kind of special heat-treated steel with very exceptional fracture propagation resistance, for general use in bridges and other structures exposed to comparatively low winter temperatures. Apart from the prohibitive cost, the steel mill capacities for producing such material would fall very far short of meeting the demands.

One might go to such extremes in design and methods of construction as to reduce notch effects to the very minimum. This would not only be prohibitive in cost, but in many cases it would impair seriously the useful-

ness of a structure because of unfavorable arrangement.

The practical engineer is continually confronted with the problem of how to write his specifications to provide an adequate margin of safety at a reasonable cost. There is a calculated risk involved in the proper solution of any engineering problem, but it is important that it be a calculated one. Research in welded structures has done much to provide for rational methods of calculating the risk of brittle fracture.

A great deal has been learned from fundamental research during the last decade about the metallurgy and mechanics of brittle failure. Much of it can be applied in choosing materials and in designing practical structures to avoid such failures. As in other engineering problems there must be a compromise between idealism and practicability. It is here that the scientists and engineers sometimes find it difficult to agree.

Brittle failures in actual structures have yielded some valuable information, at least in the form of statistics that have been useful for correlation with laboratory test data. Complexity and lack of complete information usually make it impossible to derive fundamental information from such failures. Also, the predominance of one influential factor may overshadow others to the point that little information of educational value can be derived.

The steel material involved in the early welded bridge failures in Europe was generally of such poor notch ductility and uniformity, that little fundamental information was gained from these failures at the time. Even then, the "red herring" of localized residual stresses due to welding was injected so strongly into technical discussions that, to say the least, it is still accorded much more recognition in some circles than it seems to merit. Many attempts have been made to demonstrate by laboratory research that residual welding stresses have been an important factor in brittle fractures. Attempts have been made to establish a correlation between such residual stresses and failures of actual structures. Certainly, none of these attempts has been successful in developing conclusive evidence.

There is some evidence that wide-spread areas of residual stress, called "reaction stresses," may contribute to the propagation of a brittle fracture, once it has been initiated. Also, it has been thought that they might exert an influence when very high rates of stressing are involved. However, it is well known that such comparatively wide fields of residual stress have always been present in steel structures. They result from non-uniform cooling of shapes and plates in the steel mill. When proper welding sequences are followed, the residual stresses resulting from the welding are localized rather than wide-spread. Experience has shown that very high secondary stresses, for example those in heavy truss members at riveted connections, can be neglected in design. Like residual welding stresses, they are self-limiting. As major emphasis is coming to be placed upon preventing *initiation* of fracture, the practical importance of residual welding stresses would seem to disappear.

It is important not only to differentiate between localized stresses and wide-spread fields of stress, but also to recognize the difference between temporary shrinkage or temperature stresses and so-called residual welding stresses. The former may occur at a time when the strength and ductility of the heated metal is greatly impaired. Their pattern may be different from that of the residual stress after the weldment has cooled to a uniform temperature.

It is true that fractures have started in welded subassemblies that are subjected to little if any, external loading, some little while after welding operations have been completed or suspended. However, these instances usually occur under changing conditions of ambient temperature, and frequently when localized heat is introduced with the restarting of the welding in an incompleted joint. Conditions of temporary support or restraint of a weldment, as well as influences from temperature, may result in stresses that provide an important contribution to the initiation of fracture.

However, if there are shrinkage cracks or other deficiencies in a weldment, which constitute such severe conditions that they can start a fracture under the conditions mentioned, then they would likely result in later fracture anyway, under normal service loads, apart from any influence of residual stresses.

If a member or connection, by reason of faulty details of design or defects of workmanship, cannot sustain the slight amount of straining required for mechanical relief of localized residual welding stresses, then it could hardly be expected to sustain the small localized plastic strains that inevitably occur in any practical engineering structure.

Transition Temperatures

It was not until the late 1940's[3] that it became well recognized that steel can be considered to have two types of transition temperatures, with respect to brittle fracture: (1) a ductility transition pertaining to initiation of brittle fracture and (2) a fracture transition temperature pertaining to propagation of fracture.

The ductility transition, related to *initiation* of fracture, is of course dependent upon the sharpness of notch-like defects. It must be dependent also upon the localized rate of increase in stress, which exerts a pronounced effect upon the yield stress.

The velocity of impact loading or rate of applying stress is much higher in some structures than in others. Impact tests of beams at Columbia University, which will be discussed further on, have demonstrated that under impact, higher yield stresses are developed. It is all right to exaggerate testing conditions such as impact loading, and to include the effects of the sharpest possible notches, to facilitate the study of a problem; but the results must not then be applied *directly* to practical design and construction, unless equally severe conditions are actually involved.

Further, experience indicates that notch acuity can be controlled in practical fabrication, and potential crack starters of maximum possible sharpness are not

inevitably present in welded structures. These factors must be considered carefully in adopting a ductility transition temperature that is intended to indicate the lowest safe operating temperature for a structure.

Simply for the purpose of establishing a basis for reference and correlation, it is well to define a *particular* ductility transition temperature. Such a ductility transition, the nil ductility transition (NDT), has been defined (perhaps rather loosely) by researchers, along with a fracture transition, elastic, (FTE). These may be characterized as follows:

1. The nil ductility transition (NDT), associated particularly with the *initiation* of brittle fracture (see Fig. 1). It is the temperature below which the behavior of a particular steel material *under impact loading* becomes so brittle *in the presence of the sharpest possible notch* (a cleavage crack notch) that fracture will be initiated with no significant prior plastic deformation at the root of the notch. This NDT is some 50° F below the FTE, when these transitions are determined by explosion tests and drop weight tests such as those conducted at the Naval Research Laboratory.

2. The fracture transition, elastic (FTE). It is the highest temperature at which brittle fracture, once initiated, will propagate through an elastically loaded region. Propagation may occur in a field of comparatively low stress, perhaps as low as 5000 psi in the case of ordinary structural steel.

For less acute notches, such as imperfections in well constructed bridges, the ductility transition seems to occur at a considerably lower temperature than that determined by laboratory tests that have been used to determine the above-mentioned NDT. Further, experience as well as impact tests and static tests of beams indicate that when the rate of increase in stress is decreased by decreasing the velocity of loading, the ductility transition is lowered a good deal. The rate of stressing in most bridge members is not high as compared with that of the impact tests of beams at Columbia University.

The studies of Robertson in England[4] and those of Pellini at the Naval Research Laboratory in the U.S.A.,[5] have clarified our understanding of initiation and propagation factors. Pellini and his associates have demonstrated a third transition, the fracture transition, plastic (FTP), which rounds out the picture but is of little interest to bridge or structural engineers. Above this FTP temperature (which is some 120° F above the NDT) rupture of the steel can occur only by 100% shear tearing under extreme plastic loading.

The investigations and interpretations made at the Naval Research Laboratory are especially helpful to practical engineers. This research has involved specimens that more nearly simulate actual conditions in an engineering structure, but the specimens have been kept simple enough to control variables quite well. However, the rate of loading and stressing has been comparatively high.

The Charpy V-notch impact test has become widely accepted as the most practical method of determining the notch ductility of structural steel materials. Quite a good correlation has been established between Charpy-V transition temperatures and the behavior of ships in service, as well as with large scale tests of the more commonly used structural steel materials, such as wide plate tests and the NRL explosion bulge tests and drop weight tests.

The proper Charpy-V energy level to be used as basis for determining the fracture initiation temperature for any class of structures in service varies considerably, depending upon service conditions such as expected rate of stress application, that is, how much impact is involved in the loading, as well as the severity of notch-like defects. It also depends upon deoxidation practices and other characteristics of the steel making process. For structural carbon steels, energy values from 5 to 20 ft-lb have been proposed by researchers, the higher value for fully-killed steel (see Fig. 1). Correlation with tests of large specimens has indicated that the appropriate Charpy-V energy values for some of the special heat-treated alloy steels of exceptionally good toughness are considerably higher than for structural carbon steel.

In view of the excellent service records of a good many welded bridges in cold climates, these proposed values seem to peg the lowest safe operating temperature at an unduly conservative figure for steel bridges, welded or riveted, for which reasonable care and control are exercised in design and construction.

The Role of Welding in Brittle Fracture

At the Naval Research Laboratory, Pellini and Eschbacher have evaluated the notch ductility characteristics of various common types of weld metals.[6] Explosion bulge tests have shown that it is only when the notch toughness of the base metal is greatly superior to that of the weld metal, that fractures can be made to follow welded joints (unless the temperature of testing is quite low).

By means of drop weight tests, the E6010 types of welds were found to be somewhat superior to the semi-killed and rimmed structural steel plate of $^3/_4$ to 1 in. thickness used in these tests, and essentially equivalent

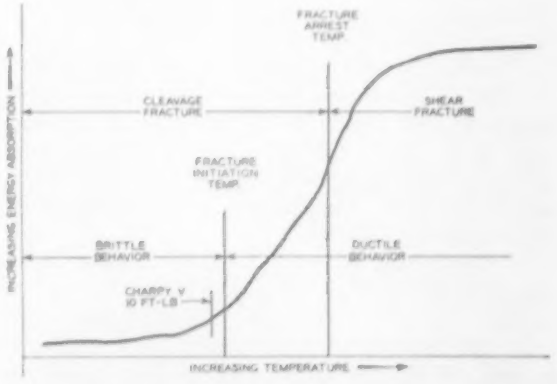


Fig. 1 Behavior of structural steel under impact loading in presence of sharpest possible notch

Fig. 2 Construction of Three Rivers Bridge, Province of Quebec, Canada, in 1947. West Crossing. Two end spans at 148 ft and six spans at 180 ft; 42-ft roadway

to the as-rolled fully-killed steel plate. The E6012 type appeared to be at least somewhat inferior.

The E7016 type, as well as the E6020 type, was found to be essentially equivalent to the E6010 type. This seems to indicate that the superior behavior of members welded with E7016 low-hydrogen electrodes is derived largely, if not entirely, from a diminution of the severity of flaws, rather than from improved metallurgical conditions.

Although the metallurgical effect upon base metal of the heating and cooling cycle during welding may be important with respect to the formation of shrinkage crack flaws, even for ordinary carbon structural steel, perhaps a disproportionate amount of importance was attributed to this factor in the earlier studies of the brittle fracture problem.

In interpreting some of his later studies, Pellini states: "The basic role of welding in the development of brittle fractures is now clear. In or near the welds, crack-like flaws may be developed for a variety of reasons. When the tips of such notches extend into the base steel, the notch ductility of the steel becomes the governing factor."

There is some evidence from practical experience to confirm this belief. A thorough examination of sources of fractures in welded structures has sometimes disclosed unmistakable evidence of sizable crack-like flaws at welded joints. Further, it has been found that service fractures correlate with the transition temperature of the unaffected base metal, rather than with the characteristics of the weld or the adjacent heat-affected zone.

Service Fractures in Welded and Riveted Structures

Research has provided information that helps one to interpret better the behavior of steel that has been observed in engineering structures that have failed.

Brittle fractures are found almost invariably in the heavy material of any large steel structure that collapses. They may be found, even in the comparatively light material of component parts of large riveted members, and when the prevailing temperature during collapse is not low. There has been a tendency among engineers to consider the brittle granular appearance of such fractures to be, in itself, an indication of inferior

structural steel material. However, under such conditions of collapse, the tremendous over stress would be expected to force initiation and propogation of some fractures of quite brittle appearance, even at temperatures 70° F or more above the lowest service temperature that would be safe for ordinary conditions of load and stress.

In January 1951, about four years after the Three Rivers Bridge had been put in service in the Province of Quebec, Canada, (Fig. 2) a local shattering, of an appearance such as would be expected from a demolition bomb, precipitated the collapse of several continuous spans of this large welded girder bridge when the temperature was 30° F below zero.[7] The local shattering simply started a mechanical "chain reaction" that caused the successive collapse of the spans of one continuous unit, letting them drop, one by one, to the river bed. The steel girders were broken in many pieces with fractures of the brittle granular type, as would be expected. However, even at this low temperature, many parts of these heavy girders were bent most severely without fracture. In evaluating the significance of the failure of this bridge, it is important to note some very unusual features and conditions, apart from the fragmentation in one localized area which convinced demolition experts that the failure was due to sabotage.

Evidence was developed by disinterested parties, leading to the belief that the concrete of the bridge floor was of the expansive type mentioned in the first part of this paper, which exhibits continued permanent growth in volume. The concrete floor was quite well anchored to the girders by shear developers and floor expansion devices, and also by the embedment of the top flanges of the floor beams.

A structural analysis made by Lamb[7] has shown that as a result of such growth of concrete, wide-spread reaction stresses of greater than normal yield point intensity might be created in steel girders of the proportions involved in this structure.[7] Under the prevailing circumstances, such stresses could initiate fracture and would surely be an important contributing factor.

In a previous investigation, prompted by the occurrence of some local fractures in the girders of this structure, about a year prior to its failure, some of the steel material at highly stressed locations, including those of initiation of these previous fractures, was found to be a rimmed steel with pronounced segregations. Although it conformed essentially to the provisions of the ASTM-A7 specification, which has been used commonly for bridge construction in the United States and Canada, this steel was of quite inferior quality as compared with that normally supplied under this specification. Further, the carbon content of some of the other steel approached 0.40 %, as determined from drillings taken from mid thickness. Some of the subsequently adopted ASTM specifications for structural steel provide definite requirements for carbon and manganese. The ASTM-A7 specification does not. The characteristics of this steel material would be expected to raise the temperature for initiation of fracture a good deal above that for a normal welded bridge.

One observation of the general behavior of this structure during collapse is of interest in connection with paths of propagation of brittle fractures in welded structures. A thorough examination of the wreckage failed to reveal any tendency of the fractures to follow any of the welds or their fusion zones or heat-affected zones, despite the low temperature of −30° F. This behavior is quite typical of the collapse of structures with reasonably sound welds, although very severe over stresses must exist in almost every conceivable direction during collapse.

Experience of this kind in ships as well as bridges has led to the belief that it has been the notch ductility of the base metal, rather than that of welded joints, that has constituted the controlling factor with regard to brittle fracture. Such experience confirms the findings from research at the Naval Research Laboratory that have been mentioned in connection with the role of welding in brittle fracture.

These research findings have been confirmed also by the previous investigation made when two fractures were discovered in 2-in. and $2^1/_2$-in. thick flanges of the girders of this same bridge, about a year prior to the failure. Traces of shop paint were found in both of these fractures, indicating the presence of small crack-like flaws that extended slightly into the base metal.[8]

The unusual characteristics of the steel material of this bridge would increase the susceptability to the formation of such crack-like flaws. A current revision of the American Welding Society Standard Specifications for Welded Highway and Railway Bridges will not only specify the use of one of the newer structural steel materials, ASTM-A373, but it will also include more definite provisions for welding procedures.

Soon after completion of the Zoo bridge in Berlin in 1935, when the temperature was 14° F, several transverse fissures were discovered in the complete penetration web-to-flange groove weld T-joints of the girders. A laboratory examination lead to the belief that the fissures had started from shrinkage cracks that occurred during shop fabrication.

Before the Rüdersdorf bridge in Germany had been opened to traffic, in January 1938, two serious brittle fractures of the girder webs started at similar T-joints adjacent to tension flanges, at a temperature of 10° F. It is well known that the structural steel material used in general for bridge construction in Germany and Belgium at that time was of much poorer weldability and notch-toughness than the American ASTM-A7 steel, and even more inferior as compared with the quality that is assured by the newer American structural steels for welding; ASTM-A131 and ASTM-A373.

When static load tests were made of welded girders, built of the same kind of steel material as was used in the early welded German bridges, to investigate the causes of fracture in these structures,[9] the presence of

very small, virtually microscopic crack-like flaws did not prevent a large amount of plastic deformation without fracture at testing temperatures carried as low as −22° F.

A comparison of the report on these girder tests with descriptions of the service fractures in the literature,[10] seems to indicate one important difference. The shrinkage cracks found in the Zoo bridge, for example, were quite sizable ones extending slightly into the base metal. The crack-like flaws that did not cause fracture in the test girders were virtually of microscopic proportions, or at the most of very small size, say 1 mm in length.

Such test results no doubt explain the reluctance that has prevailed, to believe that so-called inherent flaws of almost microscopic proportions are important factors in the initiation of brittle fracture in ordinary engineering structures.

The crack-like flaws discovered in the Three Rivers bridge in Canada were small flaws, but not of the extremely small or microscopic kind. The difference is important, because microscopic crack-like flaws are likely to be found in any cast metal such as a weld.

Pellini is emphatic in differentiating between obvious "chance flaws" in welds, and the "microscopic flaws inherent to cast weld metal." His explosion tests showed that in the presence of a sharp notch (presumably comparable to a chance flaw), any inherent microscopic flaws exert a negligible or very small influence upon the temperature at which fracture will initiate with no measurable deformation, although they do exert some influence when there are no larger chance flaws to overshadow their influence.

Thus research as well as experience seems to indicate that the practical bridge or structural engineer need not be concerned about microscopic flaws in welds or base metal. More important flaws or imperfections are inevitably introduced by any of the various fabricating operations such as shearing, punching, bending, flanging, friction sawing, rough machining, welding and rough manual oxygen cutting.

All of the fractures of welded girders that have been mentioned seem to have started at the welded T-joint between the web and one of the flanges. Some of these T-joints have been fillet welded, and others have been designed as full penetration groove welds. Such joints surely constitute critical locations. This may be caused, at least partly by restraint and multiple paths for conducting heat away during cooling after welding, which may result in crack-like flaws when welding procedures are not properly controlled. However, it should be emphasized again that the crack-like flaws or small fissures that have been discovered in the investigations of fractures in bridge girders have been obvious, though small, rather than microscopic flaws. Experience has indicated that it is at least somewhat more difficult to avoid crack-like flaws in making a complete penetration T-joint than in making a fillet welded T-joint.

Apart from the influence of any crack-like flaws that may exist in the web-to-flange joints of a beam or girder, rather severe concentrations of stress and strain have been found at such joints. More research into this behavior at T-joints would be desirable.

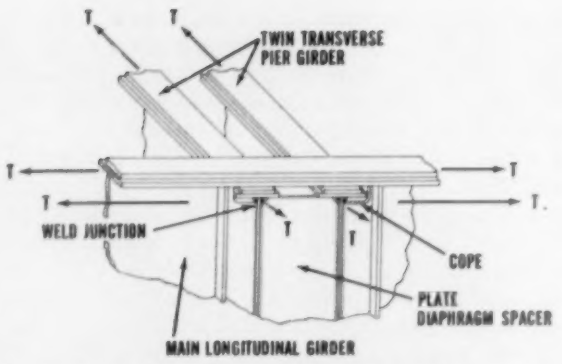


Fig. 3 Intersection of longitudinal girder with pier girders of highway overpass structure

Effect of Details of Design upon Ductility

There is a sufficient background of service experience to show that good cold weather performance can be expected of welded bridge girders, when they are properly designed, of suitable inexpensive materials, and welded with properly controlled practical procedures. The details of design need not be arranged meticulously nor refinements carried to the extent of impracticability, to accomplish this. However, the designer must be on the alert to avoid extreme degrees of constraint and concentration of stress.

For example, the structural arrangement for a highway grade separation structure built a number of years ago, involved a number of intersections of main longitudinal girders with transverse pier girders, both of which carry quite large negative bending moments at the intersection near a point of support on a pier. To avoid a field of biaxial tension in the plane of the upper flanges, the web of the longitudinal girder was coped rather generously (see Fig. 3) to provide for the upper flanges of the twin transverse girder to extend through this cope, just below the flange of the longitudinal girder, thus avoiding a direct intersection of the flanges.

The twin transverse girder-members are tied together at this point by means of a diaphragm in the plane of the web of the longitudinal girder, making this web continuous. Thus, in effect, the webs of the girders do intersect.

Therefore, the upper part of the diaphragm, is in a position to be stressed in tension due to the negative bending moment of the longitudinal girder. At the point of intersection of the girders, the upper parts of the webs of the twin transverse girder are likewise in tension due to negative bending moment. The line of intersection of the webs in this region is, therefore, subjected to quite large tension stresses applied in the two directions.

If the diaphragm spacer of the twin girder and its welded connections had been detailed to provide a

slight amount of flexibility, this would have relieved the concentration of biaxial stress and the high degree of local restraint at the upper part of the web-intersection.

The unfavorable condition was further aggravated by the cope in the web of the longitudinal girder at this point being made hardly deep enough to clear the flange-to-web fillet weld of the transverse girder. This resulted in a total of eight lines of fillet welds coming together almost at one point, in a field of biaxial tension due to load. In the returning of the vertical fillet welds across the thickness of the coped web, these returns caused a marked degree of almost unavoidable undercutting in the horizontal fillet welds at this same point, thus creating at least a dull notch effect.

Experience has shown that fractures start sometimes from points where several welds intersect as in the detail that has just been described. It may be that such an arrangement makes it difficult to avoid crack-like flaws due to unfavorable welding conditions together with multiaxial restraint against shrinkage while the welds are cooling.

After the bridge had been in service some twelve years, a fracture was discovered during a routine maintenance inspection. It started at the above described weld junction, at a web-to-flange joint in one of the twin transverse girder-members, apparently at the undercut. The fracture extended downward in the web to about midheight. A close examination showed that it had also penetrated slightly into the under surface of the $1^{3}/_{8}$ in. thick flange plate.

A careful inspection of other similar details on the same bridge revealed no other flaws or fractures. Even this unfavorable detail of design apparently constituted a marginal case for the temperatures involved, in which the probability of fracture was not very great. During the twelve years of service before the fracture and two subsequent years, sub-zero temperatures must have been encountered quite a number of times.

Another somewhat similar case has been reported in which a crack started at a trihedral corner where a load bearing stiffener at a continuous girder support was welded to the upper tension flange of the girder, as well as to the web. Since the inner corners of the stiffeners were not clipped, this resulted in the same kind of intersection of fillet welds as has been described.

In the light of experience and research findings, it should not be too difficult to select details of design that will avoid excessive local concentrations of biaxial stress and restraint.

Effect of Fabrication Operations

That serious impairment of notch ductility due to fabrication is not associated particularly with welded structures is evident from failures that have occurred in riveted ships and other structures.

World-wide data on ship failures reported recently in a London publication,[11] showed that between 1947 and 1952, fifteen ships of between 2000 and 10,000 gross tons, either broke in two or foundered, following major structural failures. Four of these were riveted. Most of the other eleven, which were welded, had been built under unusual wartime conditions.

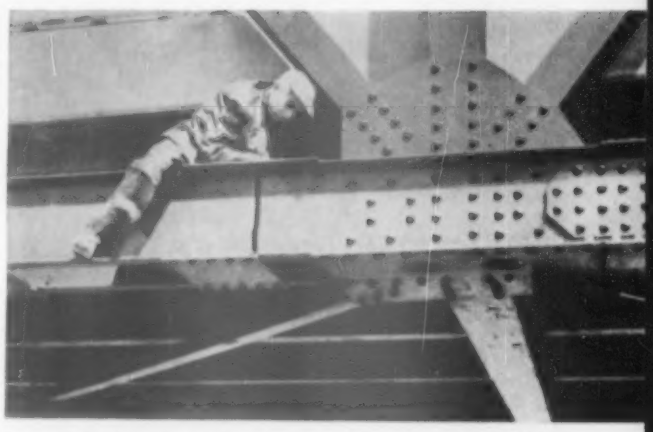


Fig. 4 Brittle service fracture in bottom chord of 200-ft span, riveted highway truss bridge

Not long ago serious fractures developed in both of two 200-foot truss spans of a riveted highway bridge in one of our northern states. The bridge was erected during the winter of 1949-1950, at a location where the temperature dropped as low as $-43°$ F, while the bridge was in service about two years, prior to the discovery of the most serious fractures in the spring of 1952 (see Fig. 4).

All of the fractures started at the rough cold worked edges of raw punched rivet holes, evidently after fabrication had been completed, because there were no traces of shop paint on the fracture surfaces. Check tests of mechanical properties, together with reports on chemistry, as well as metallographic and arc spectrum examinations, failed to disclose any abnormality of the A-7 steel material.

These most serious fractures, which occurred in service, were near midspan in a bottom chord tension member, composed of two 15-in., 40-lb channels. This thickness of material in these channels is only $^{9}/_{16}$ to $^{5}/_{8}$ in. Brittle fractures in service seldom occur in members of such proportions and thickness. Both channels were completely fractured, with breaks quite straight across. In one channel the fracture was through rivet holes at both the top and bottom of the channel.

A fracture at midlength of an upper compression chord near the middle of the other span had been discovered previously during painting, following erection and removal of falsework, but before the concrete floor had been placed. This fracture started at a bottom flange tie-bar rivet hole and extended upward to the top flange fillet. The fracture was on the concave side of a slight lateral bow in the member. The location of the fracture suggested that it might have started during handling and erection, without detection, and the member may have been over-straightened subse-

quently. The temperature was probably not lower than −18° F at the time of this fracture. Handling during erection could well have produced sufficient localized strains at the edge of the rivet hole to force the initiation of fracture at the prevailing temperature.

These fractures could likely have been averted if one of the more recently available structural steels, A131 or A373, had been available and could have been used. They could almost surely have been averted if, in addition, the rivet holes had been carefully reamed or drilled, to remove the crack-like flaws and cold worked material around the periphery of the punched holes.

There may have been some other influential factor, such as a particular susceptibility of the steel material of these bridges to strain age embrittlement, which was not disclosed by the investigation. This is suggested in view of the fact that no factors were discovered that would single out this bridge as unique. There have no doubt been a good many other steel bridges fabricated with raw punched holes and built in the northern part of the United States, of the same kind of ASTM-A7 steel. However, research that will be discussed further on in this paper, has shown that shearing and punching impair notch ductility very drastically.

State of Stress

In analyzing the brittle fracture problem, the term "state of stress" has been used commonly to include only those factors relating to geometric shape and direction of application of stress. These factors determine whether the stress is uniaxial or multiaxial and whether the total stress is quite severely concentrated at some points rather than being more widely distributed as assumed in conventional design.

For practical purposes of study and analysis, it has been convenient to investigate separately the effects of sharp local notches such as the crack-like flaws that can result from various fabrication operations. However, these effects become more serious when they are superimposed upon other geometric factors that tend to concentrate stress seriously and suppress ductile behavior.

Engineers like to think in terms of stress, considering that these factors, together with a decrease in temperature, an increase in rate of loading or of application of stress, and severe cold work, all combine to raise the yield point stress.

Ductility or notch toughness is thought of as a sort of safety valve that will permit secondary stresses and other stress concentrations to become "ironed out" before the stress rises to the point of fracture, provided that plastic deformation is not inhibited by excessive restraint or triaxiality, low temperature or high rates of stress application.

It is known that fractures can be started at temperatures quite far above the ductility transition temperature of a steel material, if the stress and the available energy are sufficiently high to force initiation of fracture, after relatively great local plastic deformation at the root of a notch. Under these conditions a ductile tear presumably can undergo a crack sharpening process if the temperature is sufficiently low. Strain aging as well as strain hardening may be an influential factor in some cases.

On the other hand, there seems to be evidence that under some circumstances, and up to a point, plastic straining can in some manner improve the cold temperature performance of a structure, particularly if the straining is not great and it is done slowly at relatively warm temperatures.

There has been some well founded conjecture as to whether some benefit may not be derived from the proof testing of structures during relatively warm weather under a slowly applied loading substantially in excess of the design load. Such proof testing or "shake down" of both riveted and welded bridges has been quite common practice for many years in Europe. For continuous frames designed by the plastic theory, such a "shakedown" might be advisable, if they are to serve at rather low temperatures.

Experience records of welded ships do not seem to indicate any general pronounced reduction of the probability of brittle fracture with increased service life. However, it is usually difficult to determine, in the case of brittle failures in service, whether the structure has even been subjected to a prior heavier loading at a warm temperature, even though it has been in service for a number of years.

In interpreting the results of practical experience as well as research, a careful differentiation must be made between initiation and propagation of brittle fracture. Comparatively small tears, or even short granular cracks, may be forced to occur at notches, without starting a fracture, because the temperature, stress and elastic energy conditions do not permit its initiation.

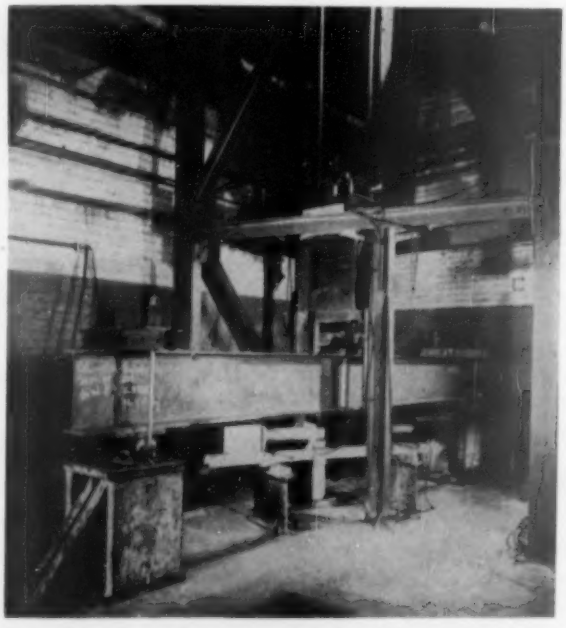
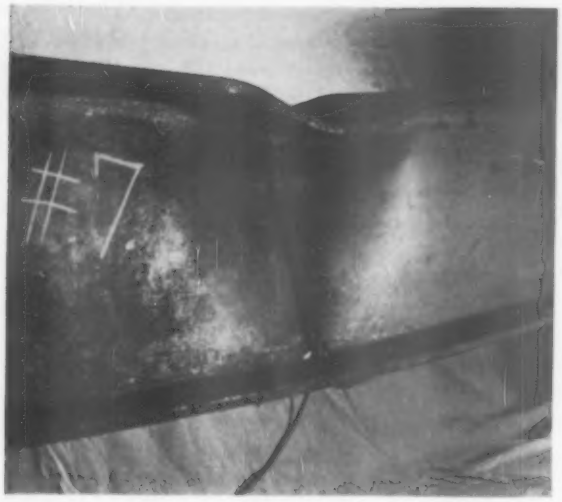


Fig. 5 Apparatus for drop-hammer load-test of 12-in. WF 71-lb beam of 12-ft span with butt-welded splice at mid-span



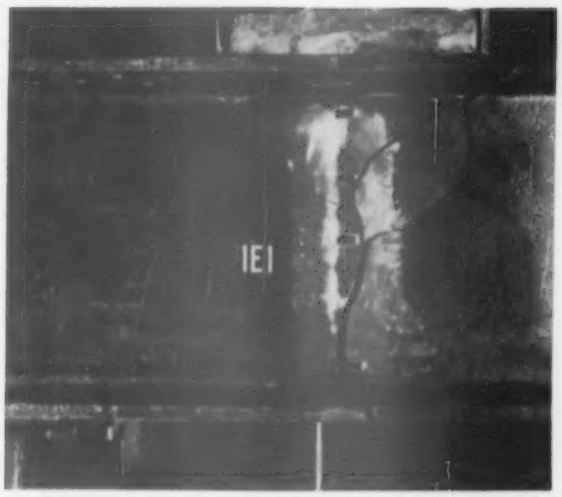


Fig. 6a *(left)* **and Fig. 6b** *(right)* **Transition temperatures of Table I are lowest temperatures at which beams failed by buckling** *(left)* **rather than by fracture** *(right)*

Also, short shrinkage cracks may occur in a weld, due to unsuitable welding procedures; but this does not constitute initiation of fracture. Such shrinkage cracks are not believed to be as sharp as a cleavage crack that is propagating.

Drop Hammer Tests of Beams

In a project of the Structural Steel Research Committee completed not long ago at Columbia University under the direction of Prof. Krefeld,[12] an extensive investigation was made of the low temperature behavior under drop hammer impact of rolled steel beams 12-in WF at 71-lb, of 12-ft span, with butt-welded splices at midspan (see Fig. 5). These specimens of $^{13}/_{16}$-in. flange thickness and $^{1}/_{2}$-in. web thickness were adopted as realistic prototypes of structural members. The program included the testing of some unwelded beams without splices but with semi-circular holes cut in the webs of the beams adjacent to the flanges, to simulate the geometry of most of the welded beams, in which such copes were provided to facilitate the making of sound butt welds in the flanges.

Some of the beams were of ordinary ASTM-A7 semi-killed steel (0.21% C, 0.57% Mn and McQuaid - Ehn grain size, 100% 1–3). The material of the other beams was of similar tensile properties conforming to ASTM-A7, but it was fully-killed steel with about 0.21% silicon and 0.047% aluminum, and had a somewhat higher manganese-to-carbon ratio (0.19% C, 0.72% Mn and McQuaid - Ehn grain size, 100% 6–8).

The beams were tested under the impact of a 2000-lb drop-hammer at various temperatures. The "transition temperatures" of Table 1 were determined upon the basis of a change in mode of failure, from buckling to fracture (see Fig. 6), except for a few beams, most of which were unwelded beams with a machined cope in the web adjacent to the tension flange, and with a sharp pressed notch in the top edge of the cope. For these beams the "transition temperature" was considered to be the lowest temperature at which failure would occur by buckling, before small tears or cracks, occurring at the root of the notch, would become extended to quite an appreciable length of granular fracture (greater than about one inch).

In many beams, local strains were determined, as close as possible to the origin of fracture in the vicinity

Table 1—Transition Temperatures* (in Degrees Fahrenheit) of Beams Tested under Drop-Hammer Impact

Beam condition	*Fully-killed steel beams*	*Semi-killed steel beams*
1. Welded with E6011 and E6020 electrodes:		
(A) As-welded	−29	− 5
(B) Welded with 350° F preheat	−57	−17
(C) Welded and Stress relieved	−45	− 5
2. Welded with E6016 (low-hydrogen) electrodes:		
(A) As-welded	−65	−25†
(B) Welded with 350° F preheat	−55	−36†
3. Coped web holes eliminated, and welded with E6011 and E6020 electrodes	−70	
4. Plain, unwelded beams with machined coped holes and sharp pressed notch	+25‡	+85‡
5. Plain, unwelded beams with coped web holes made by flame-cutting	−30	−60 to −115§

* Based on the temperature at which the mode of failure changes from buckling to fracture, except as noted for beams with pressed notches.

† This temperature or lower.

‡ Approximately the lowest temperature at which failure will occur by buckling rather than by propagation of a small tear or crack.

§ Too few tests to give more than a range of values.

of the cope near the bottom flange. As the temperature of testing was decreased, there was a marked decrease of the plastic deformation preceding fracture, in both the webs and the flanges as was expected. The deformation in the flange varied from about 0.2% at −115° F to 8% at + 30°, with a tendency for strains at the edges of the flanges to be smaller than those closer to the junction with the web, particularly at lower temperatures. Strains in the web, directly over the hole and close to it, varied from 0.2% at −115° F to 26% at + 30° F.

These data showed a concentration of stress and deformation in the web-to-flange region, with particularly high concentration in the web directly over the semi-circular cope, where most of the fractures originated. This led to the testing of some rolled beams with mid-span splices made by a more costly, but still practicable procedure, which permitted the semi-circular copes to be eliminated. This expedient lowered the transition temperature about 40 degrees. However, the same benefit might not be realized from eliminating the cope at a splice in a built-up welded girder, at a point of a high moment. The longitudinal web-to-flange welds would participate in rather high flexural stress, as well as transferring stress by longitudinal shear. It might be desirable to avoid the intersection with the splice welds.

Except for very low transition temperatures, such as the −70° F determined for beams welded without coped holes in the web, quite appreciable plastic deformation preceded the initiation of brittle fractures. Therefore one must consider the initiation to have been forced in most of the beams by a large over stress due to impact, at temperatures considerably above the ductility transition. The large over stress is confirmed by stresses that were computed by the flexure formula, from equivalent static loads that were based upon the elastic component of the observed dynamic deflection.

For the semi-killed steel, as rolled, the Charpy V-notch temperatures for a 15 ft-lb energy level were + 33° F for material in the web of a beam near the flange-to-web fillet, and + 25° F at the center of the flange. The corresponding temperatures for the fully-killed steel were −42 and −45° F. These transition temperatures varied much less for various locations in the beam, in the case of the fully-killed beams than for the semi-killed beams.

In comparing these Charpy temperatures with the behavior of the welded test beams as shown in Table 1, one must keep in mind that for the test beams, fracture initiation was forced by quite a large overstress from the impact loading; also that a good deal of deformation preceded fracture in most of the beams, at the temperatures that have been called their transition temperatures. Therefore, under ordinary service conditions, the temperature for initiation of fracture ought to be quite a good deal lower than the tabulated transition temperatures, for structures with no more serious flaws than those in the test beams.

The transition temperature for beams of fully-killed steel, as welded with E6011 and E6020 electrodes, was −29° F. For similar semi-killed beams it was −5° F. The improvement derived from the use of properly stored and conditioned low-hydrogen electrodes was very substantial and about the same as that derived from preheating (which was to a temperature higher than necessary). The two were not additive.

Correlation of Impact Test Data with Service Performance

Since there have been very few serious fractures of steel bridges in service, constructed of material comparable to either A7, A131 or A373 steel, it is impossible to make a really satisfactory comparison of their behavior with that of laboratory test specimens. However, the similarity of the beam test specimens to actual structural members, together with the general excellent performance of many welded bridges in cold climates, may justify an attempt at correlation based upon the few failures that have occurred.

When the rather extreme forcing of initiation of fracture is taken into consideration, the results of the impact tests of beams seem to indicate that a Charpy V-notch 15 ft-lb temperature would be an unduly conservative temperature to be considered as the lowest safe service temperature for a welded structure with no sharper defect than those of these beams.

In view of the ductile behavior of some beams tested under static load at a very low temperature, as well as the results of the impact tests, and after making some allowance for the thickness of material of these beams being somewhat less than 1 in., it seems reasonable to assume that most of the tabulated beam transition temperatures for impact loading are at least 35° F above the fracture initiation temperature for normal service conditions. This would indicate a minimum safe operating temperature somewhat below −40° F for a welded structure of A7 steel when welded with ordinary mild steel electrodes, and with rather severe stress concentrators such as the coped holes, or for a riveted structure with chance flaws. This temperature is of the same order as the service temperatures at which very serious fractures occurred in two bridges that have been mentioned in this paper, one of them welded and the other riveted. Much of the steel material involved in the welded Three Rivers bridge was of abnormally poor notch ductility, and other attending circumstances that have been mentioned, were abnormal, to say the least.

The use of one of the newer structural carbon steel materials would afford an additional margin of safety. A still greater margin could be afforded by the use of low-hydrogen electrodes to assure the elimination of severe chance flaws.

Effect of Strain Rate and Temperature Upon Yield Stress

In hazarding the opinions or thoughts that have just been expressed, the writer has taken cognizance of the influence of the high rate of application of load and stress, or strain producing influence, which was involved in the drop hammer impact tests of beams. Similarly, quite high rates of application of stress must be in-

volved in the drop weight tests and the explosion bulge tests made at the Naval Research Laboratory. Under usual service conditions of a bridge, the rate of increase of stress is comparatively low.

This effect has been termed variously as "strain rate," "rate of load application," etc. Engineers are accustomed to think in terms of stress and therefore prefer to do so.

The data taken from the Columbia University beam tests seem to indicate that one may interpret the effect of rate of load application and the effect of temperature, as well as that of notch acuity, in terms of stress; that is, if the stress or strain producing influence is exerted so rapidly that there is insufficient time for much plastic strain to develop, then the yield stress may be increased to a sufficiently high level to cause fracture with virtually no plastic deformation. It is further indicated that a decrease in temperature results in an increase in the stress that can be built up to produce fracture.

Pellini considers that the velocity or impact factor can be neglected in evaluating the results of the NRL explosion tests with brittle crack-starter welds, in view of the very severe notch effect involved. He feels that correlations he has established confirm this belief. It may be that the three factors, temperature, notch acuity and rate of stressing all contribute, up to a limit, in increasing the stress. Perhaps, in his tests, the combined effects of temperature plus the sharpest possible notch, plus a given rate of stressing may have raised the stress to a critical value that is sufficient to initiate brittle fracture with virtually no plastic deformation. In that event, a further increase in rate of stressing, could not increase the stress further because brittle failure would intervene. However, such crack-like defects of maximum possible sharpness do not seem to exist in welded construction over which reasonable control has been exercised.

It has been mentioned that yield stresses in the test beams were computed by the flexure formula, based upon the equivalent static loads that would produce the elastic components of the observed dynamic deflections of the beams.

A complete and accurate correlation of such computed yield point stresses with temperature or with rate of stress application, as influenced by the height of fall of hammer, is not possible for all of the tests. There were no means provided for measuring residual energy of the falling weight, when fracture occurred.

However, by comparing these computed yield stresses for various heights of fall and various temperatures of testing one finds quite a wide variation of yield stress from 64.8 ksi for a low height of fall of 54 in. and a high temperature of + 63° F, to a value of 101.0 ksi for a great height of fall of 107 in. and a low temperature of −115° F. For tests made at the same temperature, the computed yield stress increases, in general, as the height of fall increases. For tests made with the same height of fall, the computed yield stress increases, in general, with a drop in temperature.

Comparative Acuity of Notch Effects

For one series of fully-killed beams welded with E6011 and E6020 electrodes, a special welding sequence was used, which permitted the coped holes to be eliminated. These beams showed a transition temperature of −70° F. At this lower temperature of testing very little, if any, plastic deformation preceded the initiation of fracture. These beam-splice welds contained a few obvious flaws but no crack-like notch-effects.

However, when several welded beams with coped holes were tested under static loading at −100° F, they all failed by buckling, although one fully killed beam tested at this extremely low temperature developed a crack at a load just below the structural yield strength of the beam. The crack started at the bottom end of the web-splice weld, at the top of the lower coped hole. It extended to mid-height of the web, but it did not extend beyond its initial formation, nor did any fracture occur in the flange under subsequent loading to buckling. Strain measurements indicated the development of appreciable permanent deformations in the web, adjacent to the hole, prior to the occurrence of the crack. Therefore even this initiation of fracture was somewhat forced.

This seems to indicate that there were no serious chance flaws in these beams, although the welding of all the beam specimens for the entire program was done under ordinary fabricating shop conditions with reasonably good but not meticulous control over the welding.

The transition temperatures as tabulated for most of the beam tests of this program might well be defined as the lowest temperature at which buckling occurred before fracture could be initiated, even by forcing at very high stress.

The beam-test transition temperatures, as specially defined for the unwelded specimens with machined coped holes and sharp pressed notches, were very much higher than for any of the welded beams. At such temperatures a good deal of local plastic deformation occurred at the notch prior to initiation of granular fractures and there were shear lips more than 0.02 in. deep. Therefore, the initiation was rather drastically forced. These particular beam transition temperatures may have been close to the FTE of the material. However, the height of fall of the hammer, required to initiate the fractures, was comparatively small. The developed yield stress may have been relatively low, likewise.

The acuity of the sharp pressed notches in these beams must surely account for initiation of fractures at much higher temperatures than for initiation in the welded beams. These notches with a root radius of 0.00075 in. could not have been as sharp as a cleavage crack notch. Further, a comparison with the results of tests of welded beams seems to indicate that none of the welds could have had flaws in them which approached the severity of the sharp pressed notch.

Effects of Oxygen Cutting and Shearing or Punching

Tests of plain unwelded fully-killed beams with coped holes made by manual oxygen cutting showed these beams to be equivalent in notch toughness to as-welded beams welded with ordinary mild steel electrodes (Table 1). For some reason, the few semi-killed, unwelded beams with oxygen cut copes had to be carried to exceptionally low temperatures to make them fail by fracture.

Tör, Ruzek and Stout have made bend tests at Lehigh University of small specimens with similar semi-circular notches to study the effects of machine oxygen cutting and shearing or punching on notch toughness.[13] Transition temperatures determined on two bases, lateral contraction and energy absorption, were found to be comparable. Two steels were used, ASTM-A201 and ASTM-A285, $^5/_8$ in. thick.

Harris has studied the same problem at the University of Illinois using static tension tests of unnotched bars $^3/_4$ in. thick, made for Committee 15, AREA.[14] His tests involved steels conforming to various ASTM specifications: A7 (semi-killed) and A7 (rimmed), A94 structural silicon steel, and A242 low-alloy high-strength steel.

The notch bend test used at Lehigh University, being a more searching and discriminating test than the tension test, showed that even machine oxygen cutting lowered notch ductility somewhat but not nearly as much as shearing or punching. It was shown that subsequent heat treatment at 1150° F improved both the flame cut and sheared edges noticeably, and heat treatment at 1600° F was especially beneficial, lowering transition temperatures for both oxygen-cut and sheared specimens to below −160° F. The authors consider this very beneficial effect of heat treatment to be strong evidence that the very adverse effect of shearing and the moderate effect of machine oxygen cutting are not due to the formation of tiny notches at the surface, but rather are due to metallurgical changes in the metal resulting from heating or plastic deformation. However, the authors recognize the possible effect of the furnace atmosphere of the 1600° F treatment in causing scaling and sloughing off a few thousandths of an inch of metal.

Unfortunately, the program of impact tests of beams at Columbia University had to be terminated without testing any beams with oxygen cut coped holes subjected to subsequent heat treatment.

With the tension test, Harris was unable to detect any adverse effect of machine oxygen cutting on any of the steels tested other than structural silicon steel, A94. However, manual oxygen cutting "of a quality that would be expected of a novice" did lower the notch ductility of all the steels. It was believed that the quite obvious irregularities of this rough manual cutting constituted or created sizable notch effects. No attempt was made to determine whether subsequent heat treatment would improve such manually oxygen cut edges. Since it improved the sheared edges, it would be expected to improve the manually oxygen-cut edges, likewise.

The Illinois tests of all four steels showed that, by far the most serious impairment of ductility resulted from shearing. The sheared specimens of A7 semi-killed steel showed about 5% elongation in the tension test at −67° F. The impairment due to shearing of the A7 rimmed steel and the A242 and A94 steels was very great, with almost no elongation even at temperatures only slightly below + 80° F. All of the sheared specimens of A7 rimmed steel fractured at very low stresses, some of them at stresses of approximately yield point value.

As in the case of the Lehigh tests, subsequent heat treatment of the sheared specimens of all steels investigated improved their ductility greatly. In fact, the University of Illinois tension tests indicated full restoration to provide strength and ductility equal to that of specimens with machined edges. Their heat treatment consisted of applying the heat from an oxyacetylene multiple flame tip directly to the face of the sheared edge. Their procedure was not controlled very accurately, but rather it was made to simulate practical shop operations. The edge was heated

Table 2—Carbon, Manganese and Silicon Requirements for Plates

	To $^1/_2$ in., incl, in thickness		*Over $^1/_2$ to 1 in. incl, in thickness*		*Over 1 to 2 in. incl, in thickness*		*Over 2 to 4 in. incl, in thickness*	
	Ladle	*Check*	*Ladle*	*Check*	*Ladle*	*Check*	*Ladle*	*Check*
Carbon, max. percent								
ASTM—A373	0.26	0.30	0.25	0.29	0.26	0.30	0.27	0.31
ASTM—A131	..	..	0.23	0.27	0.25	0.29	0.25	0.29
Manganese, percent								
ASTM—A373	..	..	0.50 to 0.90	0.46 to 0.94	0.50 to 0.90	0.46 to 0.94	0.50 to 0.90	0.46 to 0.94
ASTM—A131	..	..	0.60 to 0.90	0.56 to 0.94	0.60 to 0.90	0.56 to 0.94	0.60 to 0.90	0.56 to 0.94
Silicon, percent (Same for A373 & A131)	..	..	..	..	0.15 to 0.30	0.13 to 0.33	0.15 to 0.30	0.13 to 0.33

Phosphorus, sulfur and copper requirements for A373 & A131

	Ladle	*Check*
Phosphorus, max. percent	0.04	0.05
Sulfur, max. percent	0.05	0.063
Copper, when copper steel is specified, min. percent	0.20	0.18

Note: for material over 1 inch thick, A131 requires fine grain practice.

"uniformly and progressively to a red heat visible in ordinary shop light to a depth of at least 1/16 in." Checks with crayon-type temperature indicators which are only approximate under such circumstances, indicated that the maximum temperature achieved in this manner exceeded 1250° F.

Prevention of Brittle Failure

Considerations of practicability have required a three-prong attack to prevent initiation of brittle fracture in engineering structures such as bridges, that must serve at rather cold atmospheric temperatures.

1. An improvement of steel material and its uniformity, without untenable increase in cost.

2. Selection of details of design that will avoid severe local constraint and serious concentrations of stress in the vicinity of critical points of a structure—without going to such extremes as would involve unreasonable increase in cost or impaired usefulness of a structure because of unfavorable arrangement. Experience and research both afford criteria for such a selection of details of design.

3. Control over workmanship to minimize the severity of notch-like flaws, without involving needless increase in cost due to meticulous and impracticable procedures.

The proper engineering approach for solving the brittle fracture problem seems to be indicated clearly as having for its objective the prevention of initiation of brittle fracture, rather than prevention of propagation. Expedients like riveted crack arresters have served a most useful purpose, pending a more satisfactory solution, but they have not always accomplished their purpose.

Certainly it would be prohibitive in cost to specify steel material for the construction of ordinary bridges or ships, that would provide a fracture propagation transition temperature (FTE) comparable to the lowest anticipated service temperature. Further, experience indicates that such a provision is not warranted.

There are very few steel bridges of ASTM-A7 material that have been built in locations where the temperature never drops well below the FTE of the steel material. The vast majority serve at temperatures from 50 to 100° F below the FTE of their steel materials, many of them at temperatures far below the nil ductility temperature as determined by explosion and impact crack-starter tests. Yet brittle fracture in steel bridges, welded or riveted, has been quite rare, except when the steel material has been greatly inferior to the common run of ASTM-A7 steel, or grossly deficient welds have provided a path for a fracture to get started.

Information about propagation of fractures is of little practical importance to the bridge or structural engineer. However, it does let him know that if he does not design and build his structure in such a way as to prevent initiation of brittle fracture, such a fracture can propagate at temperatures up to the FTE (perhaps as high at 70° F) under comparatively low stress of the order of 5000 psi.

Table 3—Tensile Requirements for Structural Steel for Welding ASTM Specification A 373-54T

	Plates, shapes and bars
Tensile strength, psi	58,000 to 75,000
Yield point, min, psi	32,000
Elongation in 8 in., min, percent	21*
Elongation in 2 in., min., percent	24*

* Modified for certain thickness ranges

NOTE: Requirements for A131-53T are the same as these, except that tensile strength is 58,000 to 71,000 psi.

The performance record has been excellent for welded merchant ships built during recent years of steel material comparable to that of ASTM Specification A131-53T. With adequate improvements in steel material for welded bridge construction in continental Europe, their difficulties seem to have been solved.

Bridge engineers have a choice between two new ASTM specifications for structural steel, for any particular application, A131-53T, specifically designated for ship structures, and A373-54T, Structural Steel for Welding, Tables 2 and 3. They are quite comparable in price. The new AWS bridge specifications will likely mention only A373-54T. It does not assure quite as favorable chemistry for the greater thicknesses of material as the A131 ship steel, nor does it provide definitely for fine grain steel making practice for material over one inch thick, as A131 does. However, A373 is more readily and generally available. The selection of either of these steel materials definitely characterized the solution of the brittle fracture problem as one having for its objective the prevention of *initiation* of brittle fractures.

The better assurance of good notch ductility afforded by either of these specifications, as compared with the older A-7 specification is well worth the small additional cost, in the case of outdoor structures subjected to rather low winter temperatures.

The only substantial additional cost for these newer steel materials is in the rather small range of thicknesses, over 1 in. through 1 1/2 in. This is because the provisions of the newer steel specifications, in effect assure the furnishing of a fully-killed steel for all thicknesses over one inch. For A7 steel it is the common practice of steel mills to furnish a fully-killed steel only for thicknesses greater than 1 1/2 in. Recent research and experience indicate that for some kinds of service conditions such as those for bridges and ships, the change from a semi-killed steel to a fully-killed steel should be made at 1 in. rather than 1 1/2 in. thickness.

Experience as well as research has provided sufficient information to give designers quite a good conception of the types of details that may be used without introducing intolerable constraint or notch effects. Some details that have been discussed in this paper appear to be borderline cases for toleration in a bridge constructed of ordinary carbon structural steel such as

ASTM-A7. The use of one of the newer steels A131 or A373 increases the margin of safety.

Likewise experience and prototype tests indicate that it should not be as difficult as it has been supposed by some researchers, to control the welding of one of these newer steels so as to prevent the occurrence of sizable crack-like flaws, which some writers have assumed to be unavoidable.

One result of faulty detailing of parts for a welded structure has perhaps not been stressed as much as it merits. Grossly defective welds or welds of inadequate size and shape for the stress imposed upon them sometimes result from faulty details of design. Sometimes this is because of poor accessibility for welding, and sometimes because of carelessness in failing to detail weld grooves properly. This condition has also resulted at times from welding being introduced by workmen at places where none was intended or needed, but where the weld is in a position to participate in stress.

The hatch corner design of the Liberty Ship has been criticized widely for its geometric shape and arrangement which resulted in compounded notch effects and stress concentrations. It is not so well known that when a small group met to study the design details of the hatches of the Victory Ship, one of the important objectives was to devise an arrangement that would eliminate the lack of accessibility for good welding which had resulted in seriously defective welding at the hatch-coaming intersections, in way of the deck plating and deck-plate doublers of the Liberty Ships.

A weld that is greatly deficient in either quality or cross-sectional area may crack during early service life, if not during the actual construction operations, and thus provide a point for initiation of fracture. The outboard ends of the transverse butt welds in the deck plating of some ships afforded good examples of this behavior. The groove was prepared for automatic welding, with a very wide root face, but the last few inches were welded manually without first adapting the groove to procedures for manual welding. A grossly deficient weld area resulted.

In one case of a temporary repair, where a short local fracture had occurred in the shell of a tank, holes were drilled at the ends of the fracture, according to instructions, and the area was covered with a reinforcing plate, welded in place. It was not long before a more serious fracture occurred in the same location. An examination showed that an overzealous welder evidently had taken it upon himself to deposit a seal bead along the original crack. To make matters worse, the holes that were drilled as crack-stoppers had been made very small.

Of course, the shell plating beneath the doubler would tend to share the applied load stress. With such a small weld area, as that provided by the seal bead, and with severe stress concentration at its root, the seal bead had cracked. Since the steel was cold, the fracture could easily by-pass the small drilled hole and propagate into the shell plating.

It should be emphasized that the presence of crack-like flaws resulting from fabrication operations is one of the most important factors in the initiation of brittle fracture. They may result from punching, shearing, flanging, friction sawing, and other mechanical operations, or from welding. For welded joints, proper control of welding procedures is relied upon to eliminate such flaws.

A good deal of information has been gained from research and experience on details of design and control of workmanship. The application of such information, together with the use of suitable structural steel material of controlled chemistry would seem adequate to prevent initiation of brittle fracture in welded bridges and similar structures. This is the solution adopted by the AWS committee on specifications for welded railway and highway bridges, in preparing a revised edition of its specifications that is now nearing completion.

As in other kinds of construction, details of design can be covered only by general provisions in the specifications. These must be supplemented with good design judgment based on experience and research.

The workmanship provisions of previous editions of the AWS bridge specifications are being revised to provide more rational and specific requirements for controlled, standardized welding procedures. These include requirements relating to the use of preheat or low-hydrogen electrodes which are patterned quite closely after the admittedly conservative provisions tabulated in "Weldability of Steels."[15]

With the use of one of the newer, quite inexpensive carbon steel materials that have been mentioned, reasonable care in designing and in adhering to construction specifications is relied upon to provide safe welded bridges, merchant ships and other similar engineering structures. Experience thus far, extending over quite a number of years, together with the results of tests of prototypes of structural members, indicates that this solution should be effective and adequate.

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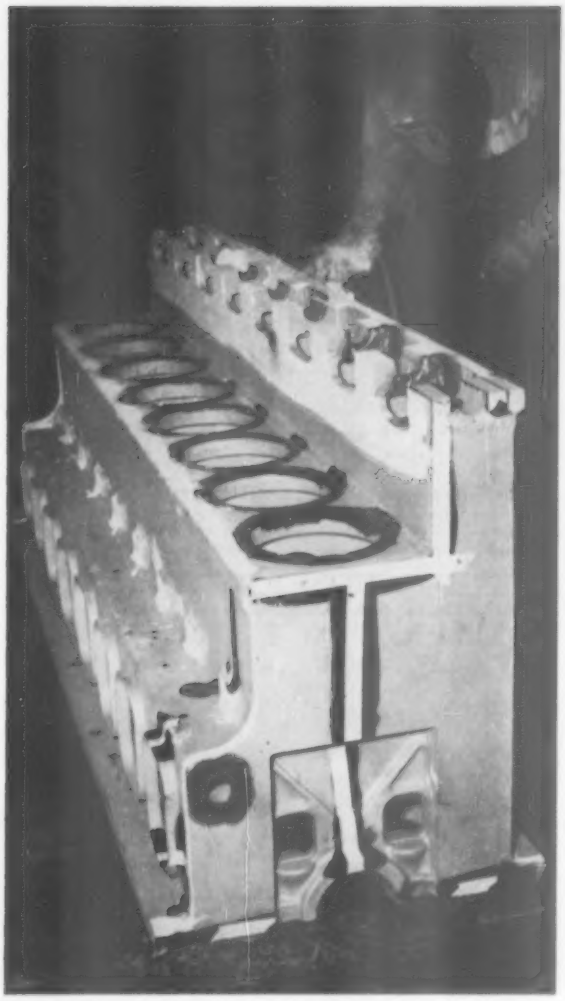

Fig. 1 Stainless steel diesel engine crankcase

PERMEABILITY AND CRACK SENSITIVITY OF STAINLESS WELDS

BY JOHN L. LANG AND CHARLES WRIGHT

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Presented at AWS 1955 National Fall Meeting held in Philadelphia, Pa., Oct. 17-21.

Authors discuss the problems encountered in obtaining stainless steel weld deposits of low permeability and high resistance to weld bend cracking

ABSTRACT. The problems encountered in obtaining crack-free stainless steel weld deposits of low magnetic permeability are presented. Factors affecting crack sensitivity and permeability of stainless weld deposits on base metal Types 302 and 304 as well as methods of evaluation are discussed.

Shop practices utilizing manual, submerged-arc and consumable electrode inert-gas-shielded arc welding of Types 302 and 304 stainless steel crankcases and flywheels are presented.

A modified Type 308 electrode consistently produced sound welds with a magnetic permeability rating of less than 2.0 μ.

Introduction

Have you ever been caught in a squeeze? That's what happened in a welding problem at our plant and here is how it came about.

The fabrication of Diesel engine crankcases (Fig. 1), gear cases, oil pans, flywheels, deck winches, etc., for the mine sweeper program presented many new problems to both the materials and welding engineer. Of primary concern was the production of a unit as nonmagnetic as practical. The selection of Types 302 and 304 stainless steel as the base material was made after considering the following: (1) Nonmagnetic, (2) weldability, (3) mechanical properties, (4) availability and (5) economy.

Type 308 stainless steel filler metal was specified because of its low incidence of microfissuring.

Preliminary laboratory tests on both base metal samples (Type 304) and manual arc-welded samples (85% Type 304 base metal plus 15% type 308 fused metal) indicated that the selected components would produce a unit which would meet a specified permeability maximum of 2.0μ. The submerged arc and con-

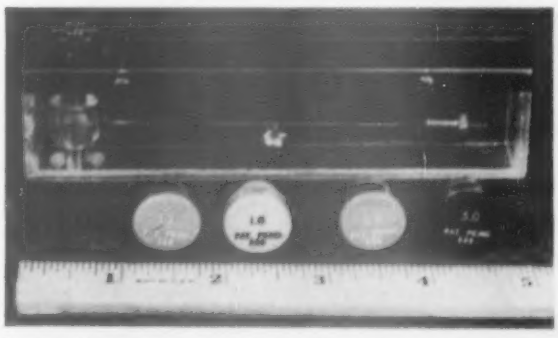


Fig. 2 Magnetic permeability indicator

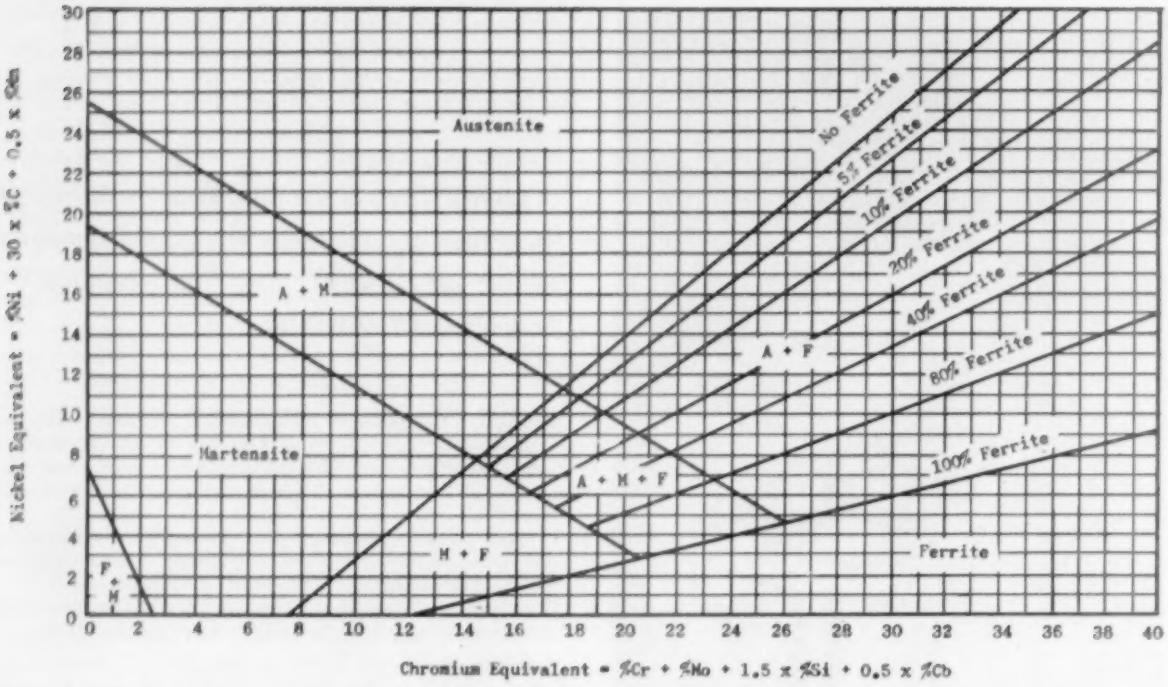


Fig. 3 Constitution diagram for stainless weld metal by Anton L. Schaeffler

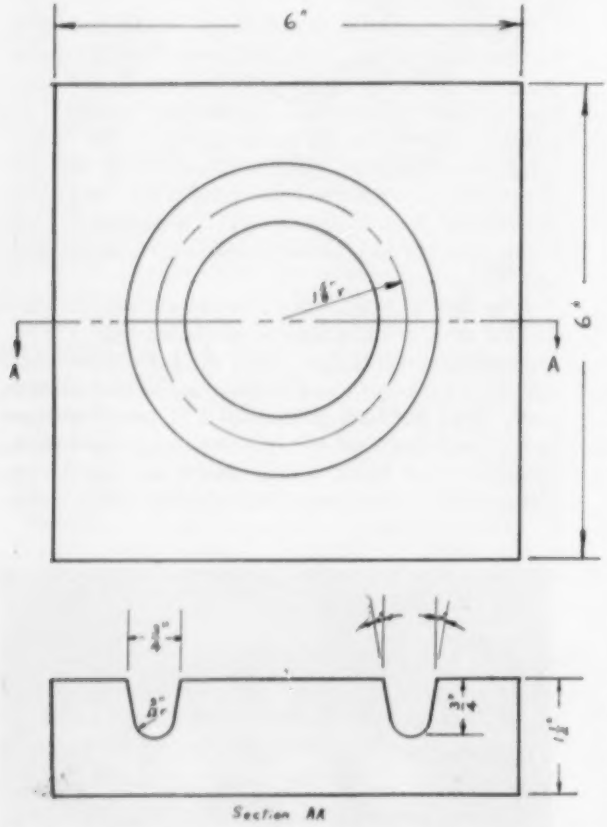


Fig. 4 Circular groove weld test plate used in permeability tests

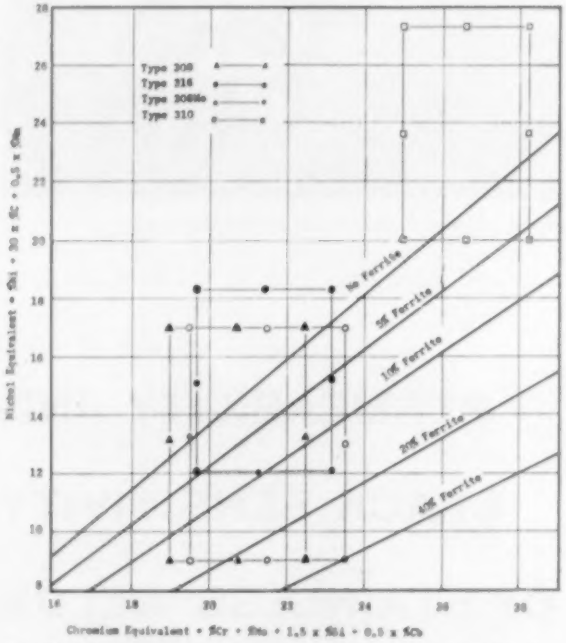


Fig. 5 Relationship between chemical limits and constitution of stainless steel weld metal as determined by Schaeffler diagram

sumable electrode inert-gas-shield arc-welding processes were subsequently qualified to this specification.

The engine crankcases and flywheels were placed in production and a number of units were produced with-

Table 1—Composition of Weld Deposits Tested for Magnetic Permeability

Test No.	Type	% C	Mn	Si	Cr	Ni	Mo
1	308	0.044	1.20	0.44	19.50	9.88	..
2	308	0.065	1.54	0.47	19.30	9.90	..
3	316	0.075	1.59	0.43	19.30	10.70	1.90
4	316	0.056	1.58	0.47	18.70	12.62	2.10
5	316	0.072	1.37	0.37	18.20	12.40	2.30
6	316	0.068	1.51	0.42	18.25	12.70	2.12
7	316	0.068	1.48	0.36	18.20	12.74	2.14
8	316	0.070	1.44	0.36	18.20	12.78	2.10

Table 2—Relationship of Ferrite Content to Magnetic Permeability

Test No.	Weld deposit, Type	Estimated % ferrite of weld deposit	Permeability rating, in./μ <1.2	1.2-1.6	1.6-2.0	2.0-2.5	2.5-3.0	3.0-3.5
1	308	8	..	..	3	5	..	2
2	308	4	4	6	..	..	..	..
3	316	3	5	5	..	..	..	..
4	316	1	8	2	..	..	..	..
5	316	0	10	..	..	..	..	..
6	316	0	10	..	..	..	..	..
7	316	0	10	..	..	..	..	..
8	316	0	10	..	..	..	..	..

Table 3—Composition of Weld Deposits Tested for Crack Sensitivity

Test No.	Type	Estimated % of ferrite	% C	Mn	Si	Cr	Ni	Mo
1	308	8	0.044	1.20	0.44	19.50	9.88	..
2	310	0	0.15	1.90	0.40	27.03	21.59	..
3	308 (modified)	0	0.115	1.90	0.35	18.41	10.38	..
4	316	0	0.039	1.66	0.34	19.10	12.68	2.02
5	316	0	0.056	1.67	0.44	19.35	12.33	2.39
6	316	0	0.062	1.73	0.36	19.23	13.15	2.16
7	310	0	0.12	1.92	0.41	26.13	21.25	..

out difficulty. Then routine checks made with the permeability indicator (Fig. 2) revealed the occurrence of sporadic areas in the submerged-arc welds on the flywheels above the specified value of 2.0 μ. Since this weld was the only one in which high permeability had arisen, consideration was given to the quenching rate of the weld deposit induced by the large mass of the flywheel. A preheating torch was attached ahead of the submerged-arc welder to reduce the quenching rates. Subsequent flywheels were produced without permeability problems.

As the engine program progressed an attempt was made to utilize the consumable electrode inert-gas-shielded arc process. The customer specified that Type 308 welds produced by this process must contain between 6 and 10% ferrite to insure against hot cracking. The welds produced met the specification on ferrite content but were not acceptable from the permeability standpoint.

The inclusion of new lots of Type 304 base plates and Type 308 welding electrodes precluded an outbreak of permeability problems which was not alleviated until the solution of the squeeze play.

Permeability of Stainless Weld

Magnetic permeability is a measure of the proficiency of a specific material in conducting lines of magnetic flux. This phenomenon is directly related to the incidence of ferrite in stainless steel.

The relationship of ferrite content to the magnetic permeability of a stainless steel weld was established through a series of tests. Eight commercial lots of titania-coated electrodes were selected with the aid of the Schaeffler diagram (Fig. 3) to provide weld metal of varying ferrite content (Table 1). Weld deposits were made from each of the eight lots on a circular grooved test plate of Type 304 stainless steel (Fig. 4). Each welded pad was tested for permeability with the permeability meter shown earlier. The results of the survey (Table 2) indicated that permeability values below 2.0 μ could be maintained by restricting the ferrite content of the weld deposit to less than 5%.

The practicality of utilizing this technique was questionable since the base plate specifications permitted a wide range in chemistry. Dilution of the filler metal by the base plate could alter the ferrite content on any one electrode.

Crack Sensitivity of Stainless Welds

The use of a fully austenitic welding electrode would insure low permeability of the weld deposit; However, the hot cracking characteristics of this type electrode produced doubt as to its adaptability to the engine program. Fully austenitic welding electrodes

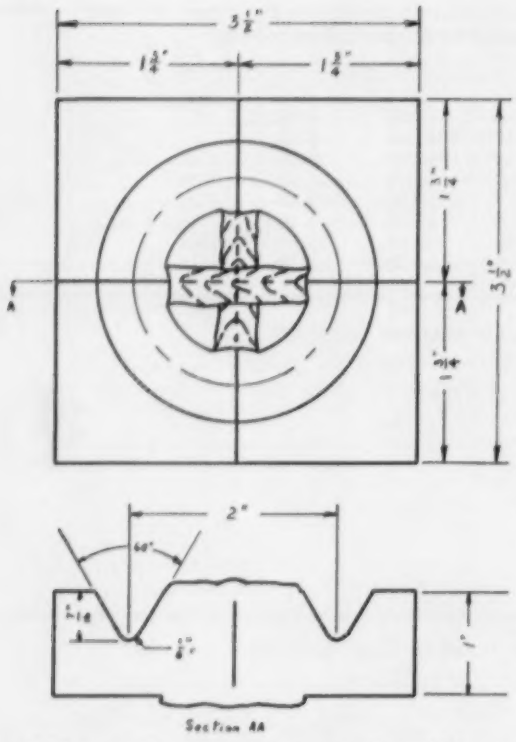


Fig. 6 Segmented circular groove crack sensitivity weld test plate

can be obtained from within the limits of a number of 300 series stainless chemical specifications (Fig. 5); however, little was known of the relative resistance to cracking of the individual type electrodes.

A series of crack sensitivity tests were conducted with segmented circular groove test pads (Fig. 6) and Type 310, 316 and 308 welding electrodes allotted to the engine program. In addition, a fully austenitic Type 308 electrode was prepared by modifying the carbon content (0.10% minimum) for comparison with the fully austenitic Type 310 and 316 electrodes (Table 3). The results of these tests showed the fully austenitic Type 308 electrode to be superior in its resistance to hot cracking (Figs. 7, 8 and 9). Here was the solution to the squeeze play. Placed in production, the modified Type 308 electrode provided a fully austenitic weld deposit with low incidence toward hot cracking.

Summary

The magnetic permeability problems encountered in fabricating Type 304 weldments were the result of the ferrite content of the deposit weld metal.

Permeability in the stainless flywheels was reduced by the use of a preheat treatment.

A modified Type 308 electrode produced sound weld deposits with a permeability factor consistently below the specified value of 2.0 μ.

Acknowledgment

The authors wish to acknowledge the technical assistance provided by the Arcos Corp., Philadelphia, Pa.

Fig. 7 Crack sensitivity test on Type 310 weld deposit—0% ferrite

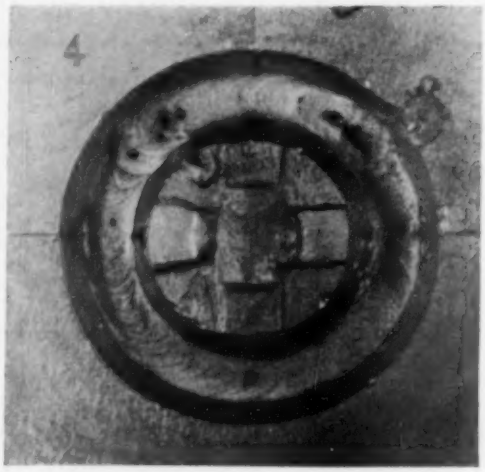


Fig. 8 Crack sensitivity test on Type 316 weld deposit—0% ferrite

Fig. 9 Crack sensitivity test on modified Type 308 weld deposit—0% ferrite

THE DEVELOPMENT AND INVESTIGATION OF HIGH-TENSILE HIGH-IMPACT ELECTRODES

Electrode developed to meet fully the as-welded and stress-relieved requirements of tensile and impact properties of a low-alloy high-tensile steel

BY G. S. WEPFER

SYNOPSIS. The recent development of low-alloy high-tensile steels such as T-1 steel, and the continued demand for the welding of armor plate led to the following investigation.

Available E12015 electrodes, conforming to Grade 260 of Mil-E-986B specification, were tested. Tensile properties were adequate in both the as-welded and stress-relieved states. Impact properties were low and were not satisfactory in the stress-relieved condition.

Manganese-molybdenum electrodes of the E9015 and E10015 types were tested and again the impact values of stress-relieved welds were low when tested at −65° F. The yield and tensile strengths of the E10015 electrodes were adequate; however, the E9015 electrodes were below the minimum strength levels of T-1 steel requirements.

Electrodes containing various combinations of alloys using a low-hydrogen type of coating were made and tested in the as-welded and stress-relieved conditions. Complete testing data, including welding procedure, mechanical properties, and impact properties of these electrodes, was analyzed.

The influence of electrode size and weld-metal chemistry on mechanical properties and on impact properties was studied. One electrode was developed which will fully meet the as-welded and stress-relieved requirements of tensile and impact properties of T-1 steel. This electrode has a composition of 3.5% nickel and 0.50% molybdenum.

Introduction

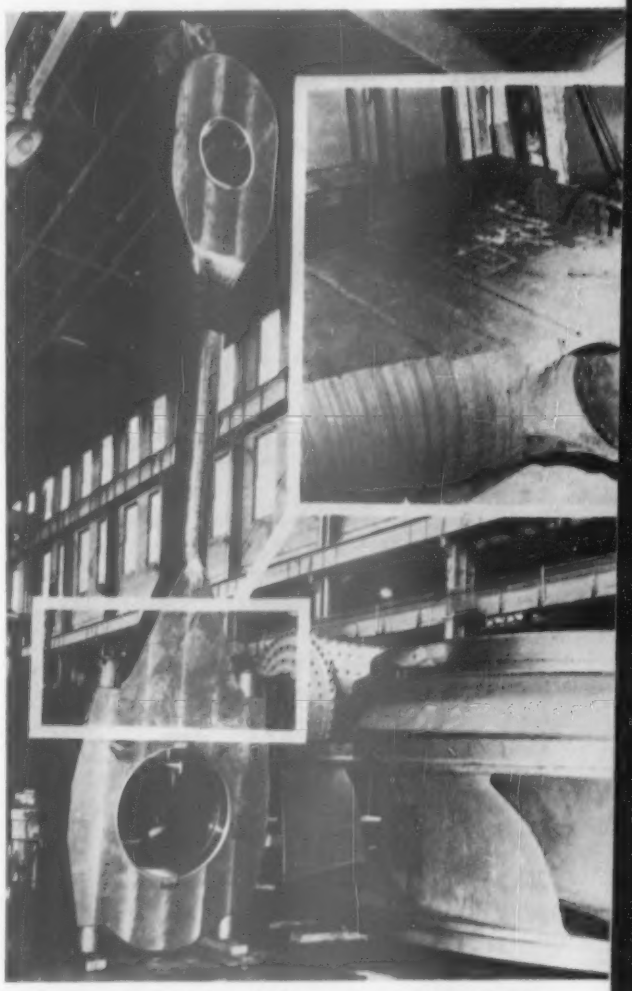
The first objective of this work was to evaluate the existing weld metal types from the standpoint of their usefulness in the fabrication of T-1 and similar steels.

If this evaluation indicated deficiencies, the second aim of the work was to attempt to develop a weld metal with satisfactory characteristics.

Investigation of Available Weld Metals

Plate Material

Various thicknesses of T-1 steels and AISI 4340+V steels were used. The analysis of the various thicknesses of T-1 steels used are given in Table 1. The 4340+V steels that were used are standard AISI type plus a vanadium addition of approximately 0.15%. The carbon content of the T-1 steels ranged from 0.17 to 0.20% and the manganese from 0.83 to 1.04%. The $^1/_4$- and $^1/_2$-in. plates contained approximately twice as much silicon as the 1- and $1^1/_4$-in. plates. Boron was found in small amounts in only the 1- and $1^1/_4$-in.



21-ft connecting rod for 1800-ton press welded with alloy "G" electrode. The welded area was 34 in. long and 14 in. thick

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Presented at AWS 1955 National Fall Meeting held in Philadelphia, Pa., Oct. 17–21.

Table 1—T-1 Steel Analysis

Plate thickness, in.	% C	Mn	Si	Cr	Ni	Mo	V	Cu	B
1/4	0.17	1.04	0.51	0.52	0.85	0.57	0.08	0.31	Nil
1/2	0.18	0.98	0.50	0.50	0.82	0.55	0.09	0.29	Nil
1	0.20	0.95	0.29	0.63	0.85	0.59	0.05	0.28	0.003
1 1/4	0.18	0.83	0.24	0.60	0.85	0.55	0.06	0.27	0.003
Avg	0.18	0.95	0.38	0.56	0.84	0.56	0.07	0.29	0.004

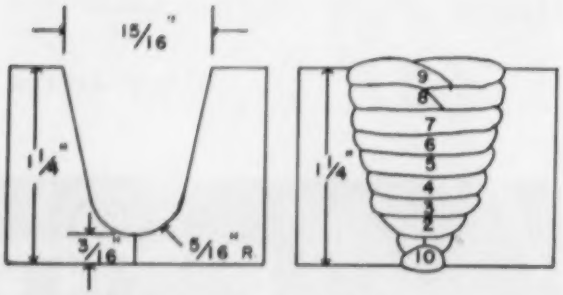

Fig. 1 Groove preparation and welding sequences employed in the welding of the 1 1/4-in. T-1 plate

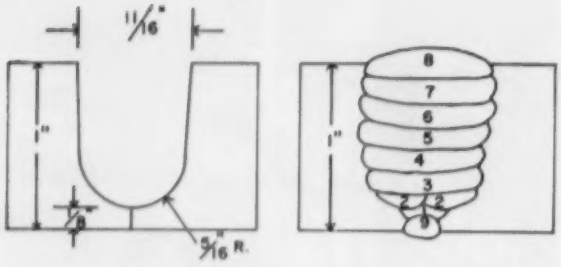

Fig. 2 Groove preparation and welding sequence employed in the welding of the 1-in. T-1 plate

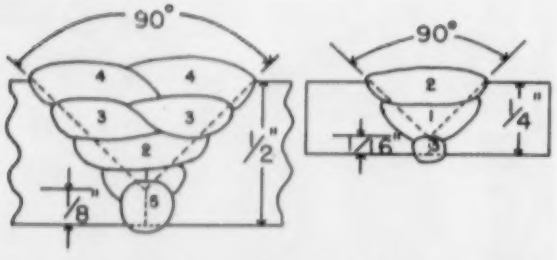

Fig. 3 Groove preparation and welding sequence employed in the welding of the 1/2-in. and 1/4-in. T-1 plate

Table 2—Mechanical Properties of T-1 Steel

Yield strength, psi, min.	90,000
Tensile strength, psi, min.	105,000
Elongation in 2 in., %, min.	16
Reduction of area, %, min.	45

plates. The alloying elements such as Cr, Ni, Mo, V and Cu were very similar in all thickness of the T-1 material. The T-1 steel that was used had been heat treated at 1650° F and tempered at 1150° F at the steel mill. The minimum mechanical properties of T-1 steel, as described in the producer's literature, are illustrated in Table 2.

Test Welds

Commercially available electrodes of various types in the desired tensile strength ranges such as E12015, E10015 and E9015 electrodes were used to weld test blocks from which the mechanical properties of the weld metal were obtained.

(*1*) *E12015 Welds in T-1 Steel.* (*a*) Weld Metal Chemistry: Electrode A of Table 7 was used to make the following welds.

(*b*) Joint Design and Welding Sequence: The thickness of the steel plate, the groove preparation and the welding sequence employed are illustrated in Figs. 1, 2 and 3.

In Fig. 1 the 1 1/4-in. T-1 steel was scarfed into a U-groove with a 3/16-in. lip and a 5/16-in. radius. The first layer was welded with 5/32-in. diam electrodes and the remainder with 1/4-in. diam electrodes. The back side was chipped out approximately 5/32 in. in depth and rewelded. All the weld metal except the 8 and 9th layers was deposited using a weaving technique; the top two layers were double beaded.

In Fig. 2 the 1-in. T-1 steel was scarfed into a U-groove with a 1/8-in. lip and a 5/16-in. radius. The first two layers were deposited with 5/32-in. diam electrodes and the remainder with 1/4-in. diam electrodes. All layers except the second were deposited as single passes using a weaving technique. The second layer was double beaded. The back side was chipped out approximately 5/32 in. in depth and rewelded.

In Fig. 3 ninety-degree V grooves were used in the 1/2- and 1/4-in. plates. The 1/2-in. plate was scarfed with a 1/8-in. lip and was welded with 5/32- and 3/16-in. diam electrodes. The first layer was deposited with 5/32-in. diam electrodes and the remainder with 3/16-in. diam electrodes. The third and fourth layers were double beaded. The back side was chipped out approximately 1/8 in. in depth and rewelded. The 1/4-in. plate was scarfed with a 1/16-in. lip. The first layer was welded with 5/32-in. diam electrodes; the second layer and back side were welded with 3/16-in.

Table 3—All-Weld Tensile Tests (0.505 Diam), E12015 Electrodes

Plate thickness, in.	Condition of weld	Yield strength, psi	Tensile strength, psi	Elongation in 2 in., %	Reduction in area, %
1	AW	92,500	104,500	21.5	60.4
1	SR	114,450	119,250	22.5	57.4
1 1/4	AW	97,900	105,100	23.5	62.5
1 1/4	SR	113,350	116,700	21.0	60.1

Table 4—Joint Tensile Tests (0.505 Diam), E12015 Electrodes

Plate thickness, in.	Condition of weld	Yield strength, psi	Tensile strength, psi	Elongation in 2 in., %	Reduction in area, %
1	AW	104,900	116,900	14.5	40.0
1	SR	106,550	118,500	15.0	47.9
1 1/4	AW	101,100	111,500	20.5	66.4
1 1/4	SR	101,750	112,900	18.5	65.6

Table 5—Joint Tensile Tests (Flat), E12015 Electrodes

Plate thickness, in.	Condition of weld	Yield strength, psi	Tensile strength, psi	Location of fracture
1/2	AW	110,000	118,000	In weld
1/2	SR	111,500	122,900	In stock
1/4	AW	111,000	121,100	In weld
1/4	SR	107,200	119,900	In stock

Table 6—V-Notch Charpy Impact Tests, E12015 Electrodes

Plate thickness, in.	Condition of weld	Location of notch	Testing temperature, °F	Energy of rupture, ft-lb		
1/2	AW	In weld	75	39.8	41.2	41.4
			−40	15.5	19.2	21.6
1/2	SR	In weld	75	14.2	18.2	15.4
			−40	5.8	6.2	5.2
1	AW	In weld	75	20.7	23.1	21.3
			−40	6.6	6.6	7.7
1	SR	In weld	75	8.2	7.2	10.9
			−40	4.9	4.8	4.3
1 1/4	AW	In weld	75	22.7	16.7	26.1
			−40	6.7	6.6	6.2
1 1/4	SR	In weld	75	8.6	6.5	7.7
			−40	4.6	4.7	4.9

diam electrodes. The back side was chipped out approximately 1/16 in. in depth and rewelded.

Preheat, Interpass Heat and Postheat Treatment

A preheat of 350° F was given to each test block and an interpass heat of 350° to 400° F was maintained during the welding operation. Upon completion of welding, the test welds were allowed to cool normally to room temperature. They were then divided into halves, one half was stress relieved for 1 to 1 1/2 hr, depending on the plate thickness, at 1150° F and furnace cooled. The second half remained in the as-welded condition.

Radiographic Examination

Radiographic examination revealed no porosity, cracks or other defects in any of the test welds.

All-Weld Metal Tensile Results

All-weld 0.505 tensile specimens were taken from the 1-in. and the 1 1/4-in. test welds. The results obtained were excellent and are illustrated in Table 3. The as-welded yield strength ranged from 92,000 to 97,000 psi; the as-welded tensile strength ranged from 104,000 to 105,000 psi. The stress-relieved yield strength was 113,000–114,000 psi and the tensile strength, 116,000–119,000. The percent elongation in 2 in. varied from 21 to 23.5% and the reduction of area from 57 to 62%.

Joint Tensile (0.505 Diam) Results

Joint tensile specimens (0.505 diam) were taken from the 1- and 1 1/4-in. test welds. The results obtained are illustrated in Table 4. Results were very good with the yield strength varying from 101,000 to 106,000 psi, the tensile strength varying from 111,000 to 118,000 psi. The as-welded specimens broke in the weld, the stress-relieved specimens broke in the stock.

Joint Tensile (Flat) Tests

Flat full thickness, joint tensile specimens were taken from the 1/4- and 1/2-in. welds. The values obtained are given in Table 5. The yield strength was 107,000–111,000 psi and the tensile strength 118,000–123,000 psi. The as-welded specimens broke in the weld and the stress-relieved specimens broke in the stock.

Impact Tests

V-notch Charpy impact tests were made from the 1/2-, 1- and 1 1/4-in. test welds. The V notch was placed along the vertical plane breaking all layers of weld metal. Table 6 illustrates the test results obtained. At 75° F testing temperature, the as-welded specimens were satisfactory; however, at −40° F testing temperature they were satisfactory only in the 1/2-in. test weld. The stress-relieved specimens had poor impact properties at both 75° and −40° F in all thicknesses of test welds with the exception of the 1/2-in. test weld at 75° F where the values would be considered satisfactory.

Summary of Results

In view of the above data, the E12015 electrode that was used could not be considered completely satisfactory for T-1 welding due to poor impact properties. The next logical move was to check whether other E12015 electrodes would give similar unsatisfactory impact properties especially after stress relieving and testing at subzero temperatures. Four different manufacturers' electrodes were obtained and test welds were made as before.

(2) *E12015 Weld in AISI 4340+V Steel.* (a) Weld Metal Chemistry: The weld metal analysis of the four different E12015 electrodes are illustrated in Table 7. Essentially the analyses are very similar, all being of the Ni-Mo-V type with slight variations in alloying elements.

(b) Joint Design and Welding Sequence: The plate material used was 7/8-in. 4340+V steel with a 20-deg over-all single-V scarf and a backing chill strip. Electrodes of 5/32 in. diam were used for the first layer of

Table 7—Weld-Metal Analyses of E12015 Electrodes

Electrode	C	Mn	P	S	Si	Ni	Mo	V	N_2
					%				
A	0.09	0.96	0.015	0.025	0.42	1.57	0.75	0.28	0.003
B	0.09	1.18	0.014	0.019	0.38	1.78	0.85	0.34	0.009
C	0.09	1.04	0.014	0.026	0.32	1.79	0.86	0.27	0.004
D	0.08	0.86	0.015	0.023	0.36	1.55	0.56	0.35	0.003

Table 8—All-Weld Tensile Tests (0.505 Diam), SR at 1150° F, 3 Hr, E12015 Electrodes

Electrode	Yield strength, psi	Tensile strength, psi	Elongation in 2 in., %	Reduction of area, %
A	118,250	119,650	5.0	11.1
	118,900	125,150	8.5	14.8
B	123,700	126,650	3.0	3.5
	126,650	134,700	6.5	8.9
C	122,550	130,550	13.5	32.8
	121,300	130,350	12.5	26.8
D	104,750	113,600	10.5	19.2
	102,150	111,750	10.5	17.7

Table 9—All-Weld Tensile Tests (0.505 Diam), E12015 Electrodes, Varying Stress Relieving Time Intervals

Electrode	Condition of weld	Yield strength, psi	Tensile strength, psi	Elongation in 2 in., %	Reduction of area, %
A	AW	116,400	126,000	20.0	55.7
	SR, 1 hr	123,900	132,700	17.0	49.5
	SR, 3 hr	116,800	125,800	16.0	41.8
	SR, 6 hr	113,200	122,100	12.0	25.3
C	AW	111,500	123,800	20.0	56.2
	SR, 1 hr	123,400	132,200	18.0	53.3
	SR, 3 hr	113,000	121,800	17.0	54.5
	SR, 6 hr	108,500	118,900	15.5	43.9

Table 10—Weld Metal Analyses of E9015–E10015 Mn-Mo Electrodes

Type	Electrode	C	Mn	Si	Mo
		%			
E9015	A	0.06	1.63	0.35	0.34
E9015	B	0.10	1.12	0.33	0.36
E10015	A	0.12	1.76	0.36	0.36
E10015	B	0.16	1.21	0.44	0.43

Table 11—All-Weld Metal Tensile Tests (0.505 Diam) E9015 Mn-Mo Electrodes

Electrode	Condition of weld	Yield strength, psi	Tensile strength, psi	Elongation in 2 in., %	Reduction of area, %
A	AW	80,750	92,250	28.5	63.6
	SR	85,750	94,950	25.5	64.8
B	AW	85,600	98,900	27.0	64.6
	SR	84,300	97,700	24.5	62.0

weld deposit and $^1/_4$-in. diam electrodes were used for the remainder of the weld. Double beading was employed instead of a weaving technique as the groove widened in the top half of the weld.

(*c*) Preheat, Interpass Heat and Postheat Treatment: A 350° F preheat was employed and an interpass heat of 350–450° F was maintained. The welds were stress relieved at 1150° F for 3 hr and furnace cooled to 600° F and air cooled.

(*d*) Radiographic Examination: No porosity or other defects were noted.

(*e*) All-Weld Metal Tensile Properties: All weld 0.505 diam, tensile specimens were made and tested. The results obtained are given in Table 8. The elongations obtained were considerably below normal.

(*f*) Impact Properties: Impact properties were determined by V-notch Charpy impact tests. The results confirmed the original results in being very poor in the stress-relieved state, especially at subzero temperatures.

(*g*) Summary of Results: Unusually low ductility was obtained after the 3-hr stress-relieving treatment. It was decided to repeat the tests using electrodes A and C. The stress-relieving time interval was to be checked to determine if the time of stress-relieving could account for the low ductility. Impact properties of the four electrodes tested were not satisfactory.

(*3*) *E12015 Welds—Varying Stress-Relieving Time Intervals.* The results of the repeat tests using electrodes A and C are given in Table 9. The ductilities obtained were substantially improved over the previous tests and we have no logical explanation for this improvement except that possibly our stress-relieving furnace had been out of control. It can be noted that there is a definite trend toward lower ductilities as the stress-relieving time increment is increased. An accompanying gradual decrease in yield and tensile strength also occurred. There are various possible metallurgical explanations for the above-mentioned decreases. Further investigations are being carried out.

Summary of E12015 Results: The E12015 electrodes would be acceptable in regard to yield and tensile strength and ductility; however, the impact properties are not acceptable for T-1 steel fabrication.

(*4*) *E9015 and E10015 Welds in T-1 Steel.* (*a*) Weld Metal Chemistry: The weld metal analysis of the E9015 and E10015 electrodes are illustrated in Table 10.

(*b*) Joint Design and Welding Sequence: The plate material used was $^3/_4$-in. T-1 steel with a 45-deg overall-single-V scarf. A $^1/_2$-in. gap and a backing chill strip was used. Electrodes of $^3/_{16}$ in. diam were used with a weaving technique for the first two layers and double beading for the remainder of the weld.

(*c*) Preheat, Interpass Heat and Postheat Treatment: The test blocks were not preheated. An interpass temperature of 190° F max was maintained. The blocks were sectioned, one part remaining as-welded and the other part stress relieved at 1150° F for 1 hr, furnace cooled to 600° F and air cooled.

(*d*) Radiographic Examination: No defects were noted.

(*e*) E9015 All-Weld Metal Tensile Properties: The mechanical properties of the E9015 electrodes are illustrated in Table 11. The yield strengths varied from 80,000 to 85,000 psi and the tensile strengths from 92,000 to 99,000 psi in the as-welded and stress-relieved conditions. The elongations were from 24.5 to 28.5% and the reductions of area from 62 to 65%.

(*f*) E9015 Impact Properties: V-notch Charpy impact tests were made, the results of which are given in Table 12. The results were good until the stress-relieved weld metal was tested at −65° F. At this temperature the impact properties were not adequate with values varying from 9.8 to 14.9 ft-lb.

(*g*) E10015 All-Weld Metal Tensile Tests: The yield strengths and tensile strengths of the E10015 electrodes were satisfactory and are illustrated in Table 13. The ductility of Electrode A was a little under the required minimum of 16% in the as-welded state. Electrode B met the ductility requirements.

(*h*) E10015 Impact Properties: V-notch Charpy impact tests were made, the results of which are given in Table 14. The as-welded impacts were satisfactory at 75, 0 and −65° F. The stress-relieved impacts were satisfactory at 75 and 0° F.; however, at −65° F we again were well below the transition temperature and the impact properties are poor with scattered values varying from 4.0 to 14.0 ft-lb.

(*i*) Summary: Both E9015 and E10015 are deficient in the mechanical properties necessary for the welding of T-1 steels that are to be stress relieved. E9015 electrodes are inadequate in yield and tensile strength as well as in impact properties in the stress-relieved state when tested at subzero temperatures. E10015 electrodes gave satisfactory yield and tensile strengths but they also failed to give the required impact properties in the stress-relieved state when tested at subzero temperatures.

Development of Special Weld Metals

Introduction

Having checked the available commercial electrodes and having found them lacking, the next stage of our investigation was to develop special weld metals and test them in a similar fashion.

Experimental E12015 Type Weld Metals

(*1*) *Composition.* (*a*) Electrode A is a typical E12015 electrode with the molybdenum removed giving an analysis of 1.80% Ni and 0.30% V. Electrode B is the same E12015 electrode with the vanadium removed giving an analysis of 1.80% Ni and 0.80% Mo.

(*2*) *Joint Design and Welding Sequence.* Joint designs and welding sequences employed were identical with those used in the testing of the E9015 and E10015 electrodes.

(*3*) *Preheat, Interpass Heat and Postheat Treatment.* The preheats, interpass heats and postheat treatments used were similar to those used in the testing of the E9015 and E10015 electrodes.

Table 12—V-Notch Charpy Impact Tests, E9015 Mn-Mo Electrodes

Electrode	Condition of weld	Testing temperature, ° F	Energy of rupture, ft-lb		
A	AW	75	87.6	94.6	82.8
		0	59.9	61.1	63.9
		−65	34.1	38.0	37.2
A	SR	75	52.8	80.6	73.0
		0	37.7	38.0	38.8
		−65	9.8	14.9	11.9
B	AW	75	60.4	73.2	64.1
		0	39.8	40.5	41.4
		−65	19.2	34.1	25.3
B	SR	75	47.1	47.1	44.6
		0	37.7	49.8	31.7
		−65	13.0	13.2	10.9

Table 13—All-Weld Metal Tensile Tests (0.505 Diam), E10015 Mn-Mo Electrodes

Electrode	Condition of weld	Yield strength, psi	Tensile strength, psi	Elongation in 2 in., %	Reduction of area, %
A	AW	94,950	112,100	14.5	26.1
	SR	99,400	110,950	24.5	59.8
B	AW	101,750	118,800	16.5	27.9
	SR	103,650	117,700	25.5	57.4

Table 14—V-Notch Charpy Impact Tests, E10015 Mn-Mo Electrodes

Electrode	Condition of weld	Testing temperature ° F	Energy of rupture, ft-lb		
A	AW	75	60.1	60.2	46.4
		0	36.1	33.8	41.3
		−65	19.9	15.4	20.5
A	SR	75	48.1	42.6	50.5
		0	27.6	26.7	29.0
		−65	8.2	13.2	9.6
B	AW	75	49.8	44.7	49.6
		0	27.6	26.7	29.0
		−65	17.9	13.1	17.9
B	SR	75	40.5	42.9	42.6
		0	23.1	19.4	14.2
		−65	7.8	4.0	14.3

Table 15—V-Notch Charpy Impact Tests, E12015 Modified Electrodes

Electrode	Condition of weld	Testing temperature, ° F	Energy of rupture, ft-lb		
A	AW	75	82.8	100.5	74.9
		0	25.3	29.8	41.3
		−65	8.2	8.8	9.6
A	SR	75	24.6	31.1	29.6
		0	16.8	10.3	7.6
		−65	6.6	6.7	8.8
B	AW	75	100.3	99.3	99.3
		0	44.4	49.5	38.0
		−65	19.9	21.2	21.9
B	SR	75	106.2	97.1	73.2
		0	38.0	32.0	36.5
		−65	7.8	7.8	13.2

(*4*) *Radiographic Examination.* No defects were noted.

(*5*) *Impact Properties.* It has been determined by the previous tests that the proper impact properties

were more difficult to obtain than adequate yield and tensile strengths. For this reason, V-notch Charpy specimens were the only tests made from the test welds made with the E12015 modified electrodes. The results obtained are given in Table 15.

Electrode A, molybdenum removed, produced satisfactory impacts at 75 and at 0° F in the as-welded condition and was also satisfactory at 75° F in the stress-relieved condition. However, at −65° F as-welded impacts were not adequate and stress-relieved impacts at 0 and −65° F were poor.

Electrode B, vanadium removed, was satisfactory at the three testing temperatures in the as-welded state and also at 75 and 0° F in the stress-relieved condition; however, the impact values fell off at −65° F and were not adequate.

(6) *Summary.* The impact properties of electrodes A and B above were not satisfactory at the subzero testing temperature.

Experimental Mn-Ni, Mn-Ni-Mo, and Mn-Ni-Cr Weld Metals

(1) *Composition.* Using a low-hydrogen type of coating, various alloy combinations were tried and test welds were made. See Table 16 for the analyses tested.

(2) *Joint Design and Welding Sequence.* The joint designs and welding sequences used were the same as in the previous tests.

(3) *Preheat, Interpass Heat and Postheat Treatment.* The preheats, interpass heats and postheat treatments were identical with previous tests.

(4) *Radiographic Examination.* No defects were noted.

(5) *Impact Properties.* V-notch Charpy impact tests were made and tested in the as-welded and stress-relieved conditions at 75, 0 and −65° F. The as-welded impact values are given in Table 16. Alloy A and Alloy C were not satisfactory due to low impact resistance at −65° F. The as-welded impact tests of all the alloys tested were good at the three testing temperatures with the exceptions noted above.

The stress-relieved mechanical properties are given in Table 17. Alloys A-C-F-H-J were not satisfactory due to low impact values at the subzero testing temperature. Alloy B was borderline and was not considered for further tests.

Alloy D had very good impact resistance but the yield and tensile strength were considerably below the minimum requirements of the T-1 steel. From the above data, alloys E, G and I were the best of the series. Further testing and study of the accumulated data revealed that alloy G gave the most consistent results.

Table 16

	Analyses of different alloy combinations — %				*As-welded V-notch Charpy*		
Type	*Mn*	*Ni*	*Mo*	*Cr*	*75° F*	*0° F*	*−65° F*
(1) A	1.00	1.75	...	...	89.1	46.8	12.7
B	1.25	1.75	...	...	70.8	46.1	25.6
C	2.00	2.25	...	...	53.4	26.1	11.3
D	1.00	3.25	...	...	106.8	61.1	54.5
(2) E	1.50	1.75	0.20	...	79.3	49.7	25.8
F	1.00	2.00	0.50	...	59.3	31.1	18.4
G	1.00	3.50	0.50	...	81.2	55.7	35.0
H	0.75	3.25	0.75	...	50.0	37.3	23.6
(3) I	1.00	3.00	...	0.50	...	...	...
J	1.00	3.25	...	0.75	...	...	...

Table 17

	Analyses of different alloy combinations — %				*Mechanical properties stress-relieved*					
					Yield strength, psi	*Tensile strength, psi*	*Elongation in 2 in., %*	*V-notch Charpy*		
Type	*Mn*	*Ni*	*Mo*	*Cr*				*75° F*	*0° F*	*−65° F*
(1) A	1.00	1.75	...	...	...	...	...	76.4	41.9	9.0
B	1.25	1.75	...	...	...	...	...	59.5	20.6	15.3
C	2.00	2.25	...	...	105,700	114,400	21.5	14.6	12.8	4.4
D	1.00	3.25	...	...	80,425	89,475	27.5	126.2	68.3	48.7
(2) E	1.50	1.75	0.20	...	94,350	104,450	24.5	63.8	30.0	21.5
F	1.00	2.00	0.50	...	94,825	104,525	24.5	49.2	22.4	7.5
G	1.00	3.50	0.50	...	99,150	108,750	22.5	63.3	39.5	21.0
H	0.75	3.25	0.75	...	102,625	114,450	22.5	39.7	23.0	8.5
(3) I	1.00	3.00	...	0.50	...	...	...	75.5	40.1	21.5
J	1.00	3.25	...	0.75	...	...	...	45.5	19.0	11.4

Table 18

Analysis alloy "G"

C, %	Mn, %	Si, %	Ni, %	Mo, %	V, %
0.06	0.96	0.29	3.30	0.64	0.02

Mechanical properties

Condition of weld	Yield strength, psi	Tensile strength, psi	Elongation in 2 in., %	Reduction of area, %
AW	96,150	109,650	21.6	55.1
SR	98,150	110,150	23.0	58.6

V-notch Charpy impact properties

	As-welded			Stress relieved		
Testing temperature	75° F	0° F	−65° F	75° F	0° F	−65° F
	77.8	52.5	33.7	62.8	35.7	19.4

Keyhole Charpy impact properties

	As-welded			Stress relieved		
Testing temperature	75° F	0° F	−65° F	75° F	0° F	−65° F
	37.0	34.1	31.5	35.9	30.3	24.6

The impact values of the alloys E and I were scattered at −65° F, revealing that the transition temperature was being approached.

Experimental Mn-Ni-Mo, Alloy G, Composition on Various Wire Diameters

Alloy G was made in all diameters of electrodes and test welds were made. The impact results obtained with the $^1/_8$- and $^5/_{32}$-in. diam were not satisfactory. The impact results with $^3/_{16}$-, $^7/_{32}$-, $^1/_4$- and $^5/_{16}$-in. diam were good. The yield and tensile strengths of the two small diameter electrodes were 15,000–20,000 psi higher than the larger sizes and the impact values obtained were below the minimum requirements. After a study of this situation, it was found that in order to obtain the proper arc stability and easy manipulative properties of the $^1/_8$- and $^5/_{32}$-in. sizes, we had coated these diameters with considerably more coating than the other sizes. This of course meant that the alloy content was greater, thus giving the greater yield and tensile strengths. A chemical analysis of the deposited weld metal confirmed the presence of more alloying ingredients. Nickel was found to be 4.80%, molybdenum to be 0.90% and manganese to be 1.25%. Reductions in these alloys were made and test blocks welded. Results now were in the proper strength levels and impact values were excellent.

Summary of Results Obtained with the Experimental Compositions

Alloys A, B, C, F, H and J were not satisfactory due to low-impact properties. Alloy D was low in yield and tensile strength; however, the impact properties were the highest of the different alloys tested. Alloys E and I were found to give erratic impact results, indicating that at −65° F they were in the transition range.

Alloy G was thoroughly tested in all electrode diameters and the results obtained were very good. A complete tabulation of the chemical and mechanical properties of alloy G are given in Table 18.

It can be seen that there is very little difference between the as-welded and stress-relieved yield and tensile strengths. The V-notch Charpy impact test was found to be a more critical test in evaluating impact properties than the keyhole notch Charpy test.

Commercial Applications of Alloy G Composition

This electrode is available commercially and has been used successfully on the following applications: (1) Successful fabrication of various thicknesses of T-1 plate (up to $1^1/_2$ in.). (2) Repair welding of high-tensile steel crank shafts. (3) Fabrication, experimental, of homogeneous armor. (4) Repair of high-tensile steel castings.

Conclusions

An electrode was developed that can be classified as an E11015 type with a chemical analysis of 3.50% Ni and 0.50% Mo. This electrode has a yield strength of 95,000 psi and a tensile strength of 110,000 psi in either the as-welded or stress-relieved conditions. The weld metal does not become embrittled when stress relieved and the impact properties are very good at both normal and subzero temperatures.

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Multispot press welder using hypersil transformers

TRANSIENT PROBLEMS WITH HIGH-FLUX DENSITY TRANSFORMERS IN WELDING APPLICATIONS

When operating resistance welding equipment, magnetizing transients may be successfully predicted when the characteristics of the welding transformer are available

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Introduction

The use of high-flux density transformers has been increasing rapidly in resistance welding installations. Typical characteristics of high flux density, or hypersil, transformers include the smaller space required for a given kva rating, lighter weight, greater ease of construction, lower losses and higher permeability and generally lower maintenance costs.

These features have permitted the design of more compact press welders using a large number of transformers in close proximity, and of portable gun stations which may be grouped more closely within a given area.

The widespread adoption of these transformers has,

however, emphasized the importance of attendant transient problems. Sources of these transients will be described in the following article together with means of reducing their effects or eliminating them.

The Problem

The practical application of hypersil transformers to resistance welding processes has not been without its problems. The fundamental one is to initiate a current in the primary of a transformer which transforms the relatively low-current high-voltage primary circuit into a high-current low-voltage secondary circuit suitable for making a resistance weld.

Primary transformer voltages are usually 220 to 440 v with currents of 40 to 10,000 amp. Secondary voltages usually range from 4 to 30 v with currents of 2000 to 50,000 amp. The ignitron contactor is generally used for the primary switching mechanism. It has the desirable feature of being subject to control from its own ignitor which acts as a control electrode requiring relatively low power for operation.

The welder control, either mechanical or electronic, serves to complete the ignitor circuit and controls the contactor.

The Welder Transformer

The discussion which follows applies to any ferrous core transformer. The operation of hypersil cores varies only in the matter of magnitude of the operating values.

A typical hypersil gun station transformer has a rating of 75 kva. Its size is approximately 16 by 12 by 9 in. The dual primary winding allows either 220- or 440-v connection and generally includes two tap switches which allow for adjustment of secondary voltage. The secondary windings are usually two independent units each consisting of a single turn of copper. These can be connected either in series or in parallel. The turns ratio of the transformer may be adjusted from approximately 66 to 1 to 44 to 1; or, each secondary open-circuit voltage range from approximately 6.9 to 10.1 v. By using the series parallel arrangement it is then possible to adjust the output voltage from 6.9 to 20.2.

For normal operation a transformer might have primary taps set on hi-five with secondary windings in parallel. Some idea of the operating characteristics may be gained by viewing the magnetization curve under 460 v excitation (Fig. 1).

This figure shows the magnetization curve of a hypersil 75 kva transformer on hi-five tap, secondaries in parallel, with 460 v applied to the primary. Observe the sharp break in magnetization curve and also the narrow hysteresis loop which indicates low losses. Figure 1 shows that the hypersil transformer may be operated at flux densities well beyond the knee of the magnetizing curve during the 20 or 30 deg before and after the peak of the sine wave of flux. Thus, a high magnetizing current is required for perhaps as much as one third of each cycle and the normal steady-state magnetizing current exhibits a sharply peaked wave.

Figure 2 shows the magnetizing current required for the same transformer operated, however, on hi-six tap, 460 v impressed. Note that the magnetizing current in this case reaches approximately 115 amp peak and 35 amp rms. This, too, is a steady-state magnetizing current as we have not considered the starting transient. This oscillogram is for one cycle only. The peak of the magnetizing current occurs at approximately 180 deg on the voltage wave, that is, at the zero of the voltage wave and it can be seen that the sine wave of current before the knee of the curve is barely discernible on the oscillogram.

Harmful Effects of High Magnetizing Transients

A magnetizing current occurs every time the primary circuit of the welding transformer is energized. Because of the sharp angular characteristic of the hysteresis loop, the transient may rise to a value of 10 or more times its steady-state peak value. While this transient current does not appear in the secondary circuit, it does cause unduly high mechanical stress on the welding transformer primary windings, the supply transformer windings and on the primary side cables. A thumping noise and higher frequency hum in the transformer is indicative of the presence of transients. Furthermore, possible saturation of supply transformer due to the d-c component may blow line fuses or trip circuit breakers. The high transients may cause premature failure of ignitrons, although there is no method of measuring the extent to which the tubes may be damaged. The transients may also have harmful effects on control equipment, either for the same welder or for other welder controls or associated electronic equipment on the line. In some cases the effect may be so pronounced as to cause relays to chatter or to drop out.

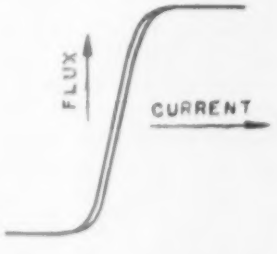

Fig. 1 Magnetization curve—hypersil 75-kva transformer—HI-5 tap, 460V

Fig. 2 Magnetizing current—hypersil 75-kva transformer—HI-6 tap, 460V

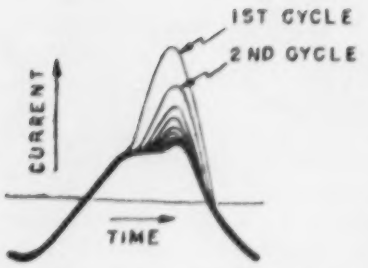

Fig. 3 Primary welding current, first half cycle initiated too early

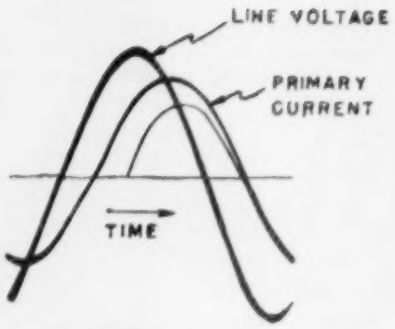

Fig. 4 Transformer current with no visible starting transient

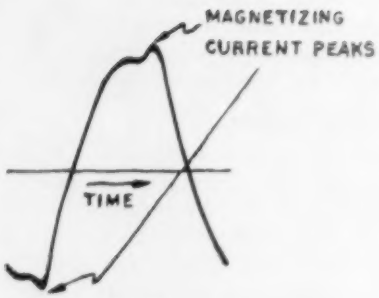

Fig. 5 Transformer primary current with HI-parallel tap, 525 v impressed on 440-v winding

Magnitude of Transients

"Just how serious is the transient problem?" has been asked for years and the causes and cures of transients are much less mysterious than they once seemed. The magnitude of all effects can be kept within bounds by using control equipment properly designed for the job.

A good understanding of what goes on in hypersil transformers will make the problem less obscure although it is unfortunate that the use of an oscilloscope in this study may tend to overemphasize the importance of the transient current. The severity of the transient should be judged by the value of the peak current rather than by the ratio of the transient peak to the load current. Often a particular value of transient peak looks extremely high when compared to a low load current, but is not noticeable when superimposed on a higher load current.

Transformer theory shows that the most severe transient condition would require a maximum flux peak during the first cycle of the weld equal to twice the steady-state flux peak, plus whatever residual magnetism was left in the core from the last weld. Refer again to Fig. 1 and imagine how much magnetizing current it takes to nearly double the flux. This condition exists when the weld current initiation occurs at voltage zero, and the current drawn would be enormous. Fortunately, it is limited by the primary resistance of the transformer and by line impedance, although it is still possible to get transients of 8 to 10 times this maximum steady-state current.

Although most of the troubles with hypersil transformers will be caused by these magnetizing transients, there is also a load circuit transient involved. This transient is limited to 200% of the maximum steady-state current because it has the nature of an air core inductive load and will die out within $1^1/_2$ cycles for loads having power factors of 30% or higher. The formula for this load transient time constant is written:

$$TC = \frac{1}{377}\sqrt{\frac{1}{PF^2} - 1}$$

Then $3TC$ = 1.5 cycles for PF = 0.30, where TC = Time Constant and PF = Power Factor.

Returning to the magnetizing transient, Fig. 3 shows it exceeding the maximum of the primary current wave while welding. This is caused by initiating the first half cycle too early and the peaks are on the lead half cycle. Each sweep is of one cycle duration and all sweeps are superimposed upon one another so that the first cycle, second cycle and so forth can be observed. The first half cycle shows the high transient with successive ones dieing out.

When the weld is initiated too late, the peaks are on the trail half cycle and look the same as in Fig. 3. It can, therefore, be determined whether initiation is too early or too late by observing whether the peaks are on the lead or trail half cycles.

Control of Magnetizing Transients

The question then becomes, "Can the objectionable starting transient be eliminated?" The answer is *yes* if the following conditions are met, and if the lack of noticeable transients on an oscilloscope screen is accepted as evidence that transients, if any, are insignificant. The conditions may be itemized:

1. The first half cycle of the weld must be initiated within proper limits.
2. Each half cycle after the first must be allowed to start immediately after its predecessor, without gaps in the current wave.
3. The welder tips must open and remain open for at least one-quarter cycle between spot welds.
4. The discharge resistor must be greater than 100 ohms.
5. The *squeeze time* must be long enough to allow the electrodes to close before welding current is applied.

Figure 4 shows the primary welding current with no visible starting transient. The line voltage reference is indicated on the oscillogram. The primary current was initiated at or near line voltage maximum in order to satisfy the no-transient condition. The other conditions were also realized. Incidentally, the aforementioned requirements assumed an installation without heat control. The use of heat control will be discussed later.

It is possible to get a picture as shown in Fig. 5. This is not a transient but is the steady-state condition when the magnetizing current peaks are high enough to project beyond the top of the current loops. This condition was attained by using the high parallel tap with 525 v impressed on the 440-v winding. This is not an objectionable or troublesome condition.

With all the facts in mind, let us examine the initiation point of the first half cycle more closely. Results obtained when using the high tap with parallel secondary connections must be examined cautiously since this connection erroneously appears to produce the highest transients. With the series secondary connection, the initiation point appears to be much less critical. Actually there is no difference between the transient characteristics for the two secondary connections. The only real difference is that for the series connection the primary current becomes twice as high for the same welding current because the turns ratio is only half what it is for the parallel connection. For load power factors ordinarily encountered, this higher primary current swallows up the magnetizing transient so that it looks smaller. Within a much wider range of initiation point settings, the magnetizing transients broaden out the primary current pulses and they are no longer noticed. Initiation angles which seem to give a large transient peak ratio with the parallel connection show a scarcely noticeable transient with the series connection, although measurement shows that the transient peaks are the same.

In determining the proper initiation angle, the most important factor is the normal starting point for the steady-state magnetizing current. This would be 90 deg after a line voltage zero for an ideal transformer, but is actually somewhat earlier because of the IR drop in the primary circuit and line, residual flux, hysteresis and eddy current losses.

Starting at the normal point for magnetizing current will normally introduce a load circuit transient because the load circuit is always higher power factor than the magnetizing circuit. This transient tends to cause higher trail half-cycle peaks, but the effect is much smaller than the magnetizing transient and it dies out much quicker. Usually, this effect is not even noticeable.

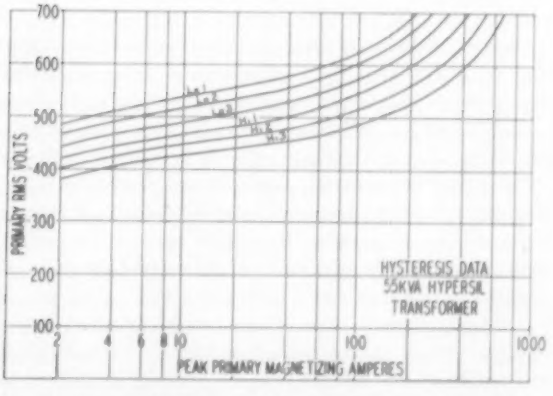

Fig. 6 Hysteresis data—55-kva hypersil transformer

Prediction of Peak Magnetizing Transients

Peak transient currents for various initiation angles can be predicted. The welder control which has the proper tolerance limits may then be selected for use with a particular welding transformer.

The following information is required to predict the peak transient current of a given transformer for any line voltage and initiation angle:

1. Hysteresis curve.
2. Phase angle of the primary of the transformer.
3. Line supply voltage.
4. The initiation angle from voltage zero.

The peak transient current can then be found by a direct graphical solution. Predicted values within 10% of measured values may be expected.

The hysteresis curve may be determined by experimental means or may be prepared from data supplied by the transformer manufacturer.

Figure 6 shows the peak primary magnetizing current versus the primary rms voltage for a 55-kva press type welding transformer. The relationships between the current and voltage are shown for the various taps on this particular transformer. It is desirable to obtain this data from the transformer manufacturer since it is difficult to determine outside of a laboratory. The data for Fig. 6 was determined experimentally by energizing the primary circuit of the transformer through a magnetic contactor with an open secondary circuit. Steady-state peak magnetizing currents were read on a calibrated oscilloscope. These data are somewhat difficult to take since the closing of the magnetic contactor will create transients, and a "stiff" power line is required, particularly at the higher line voltages.

Another acceptable method using an ignitron contactor may also be used if the necessary precautions are taken. In this case the primary circuit is loaded with a resistance load sufficient to maintain ignitron conduction (approximately 40 amp) and the voltage across the transformer primary must also be corrected to allow for ignitron contactor voltage drop. An electronic ignition circuit is employed to minimize the starting transient and a calibrated oscilloscope is used to measure the steady-state peak primary currents. At least one minute must be allowed between readings to allow the circulating currents to decay. Current readings must be corrected because of the resistance load, although at higher voltages this correction may be ignored. Care must be observed in taking readings at high line voltages since the voltage drops in the line and the regulation of the test transformer may limit the peak currents producing errors in the data. Figure 7 shows a similar curve for a 125-kva gun welder type transformer that has only two taps. These data were furnished by the manufacturer and were checked and extended by experimental methods described previously.

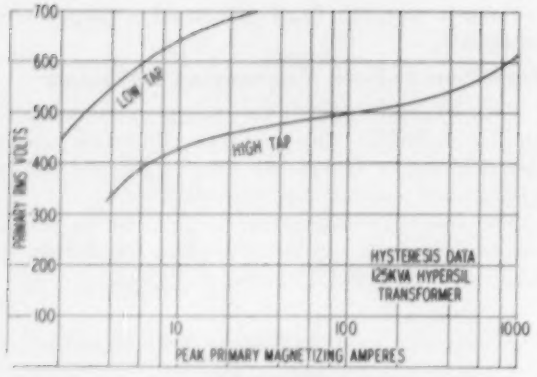

Fig. 7 Hysteresis data—125-kva hypersil transformer

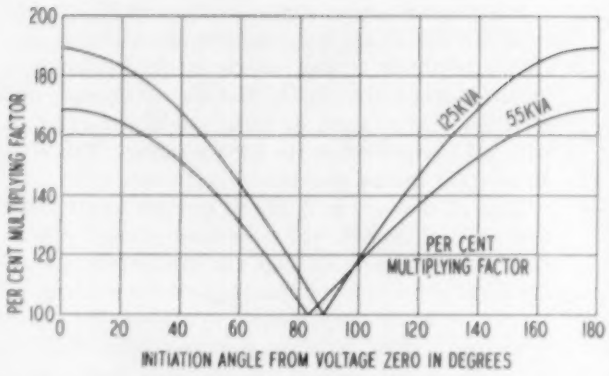

Fig. 8 Per cent multiplying factor

An important factor which is usually overlooked in discussions involving proper initiation angle for transformers is the phase angle of the primary of the transformer itself. This angle is determined by the relationship of the magnetizing current to hysteresis and eddy currents. The hysteresis and eddy currents are sinusoidal and in phase with the applied voltage. The magnetizing current on the other hand is non-sinusoidal and in the same phase relation with the flux curve. When these currents are added in their proper phase relations, the resultant is the no-load current of the transformer. It is not sinusoidal and does not go through zero at 90 deg with respect to the impressed voltage. In the practical transformer, this angle occurs somewhere between 83 and 88 deg with reference to line voltage zero. This is the proper angle of initiation.

This angle is referred to as the phase angle of the primary of the transformer. It can be accurately determined by means of an oscilloscope.

Several methods are available to determine the percent multiplying factor which utilizes this information. For simplicity, the formula is presented:

$$\text{Percent multiplying factor} = 100[\sin(\theta - \alpha) - \sin(\alpha - \varphi)\epsilon^{-(Ri/L)}]$$

where

α = initiation angle in degrees.
φ = phase angle of primary in degrees.
θ = angle where transient peak occurs in degrees.
$t = \frac{\pi}{180}\left(\frac{\theta - \alpha}{\omega}\right)$ sec.
$\omega = 2\pi f = 2\pi \cdot 60$ radians/sec.
$L/R = \tan \varphi/\omega$.

The first solution of this equation is based on trial and error in order to solve for the angle where the transient peak occurs. The phase angle of the primary is determined by measurement. The initiation angle is assumed to be zero, since this will result in the maximum percent multiplying factor. Arbitrary values of θ are then chosen to solve for the maximum percent multiplying factor. For all practical purposes, θ is constant for all values of α.

When θ has been determined from the trial solutions, the equation is solved to determine the percent multiplying factor which corresponds to various initiation angles. These data are presented in Fig. 8.

Figure 8 shows the relationship between the initiation angle in degrees and percent multiplying factor for two transformer phase angles. It should be noted that the initiation angles vary between the two transformers if a constant multiplying factor is selected. For this reason it is not desirable to attempt to set precise limits on initiation angles for controls which may be used with all types of hypersil transformers. The initiation angle tolerances must be selected with care in order to arrive at the most practical and economical result. However, if an absolute minimum transient is required, it appears desirable to have means available to adjust the initiation angle to "match" the welding transformer.

Figure 9 shows a family of curves, one for each of the taps in the welding transformer, and the relationship between initiation angle and peak magnetizing transient. By arbitrarily limiting the peak magnetizing current to any specific value, the bounds of the initiation angle may be determined which will contain the magnetizing transient within those limits. Note that this particular transformer has a phase angle of approximately 83 deg. The solid lines indicate 440 v, or rated voltage, values. The dotted curve shows 460 v impressed on hi-six tap. Note that the initiation angle range is less in this case.

Figure 10 displays typical curves for another transformer, a 125-kva gun welder type. This particular transformer has only a high and a low tap. Here again the same analysis can be used to predetermine the initiation angle for any value of line supply voltage.

It would be well to re-emphasize that the magnetizing transients do not show up in the actual welding current. In most cases the effects are not noticeable. The transients actually reduce the secondary currents slightly because of the IR drop in the primary and line which reduces the voltage available to the load circuit. Thus, magnetizing transients always decrease the welding current rather than increase it, and transient peaks do not occur in the secondary.

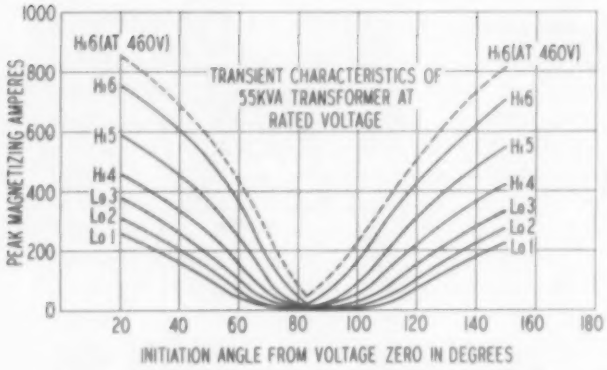

Fig. 9 Transient characteristics of 55-kva transformer at rated voltage

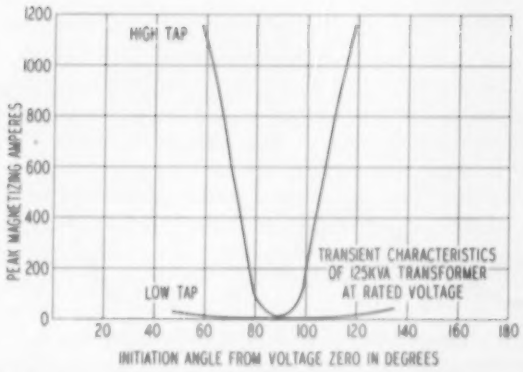
PEAK MAGNETIZING AMPERES
INITIATION ANGLE FROM VOLTAGE ZERO IN DEGREES
HIGH TAP
LOW TAP
TRANSIENT CHARACTERISTICS OF 125KVA TRANSFORMER AT RATED VOLTAGE

Fig. 10 Transient characteristics of 125-kva transformer at rated voltage

The affect of changing the power factor of the load to a very low value of 20 or 30% would tend to cause the magnetizing peaks to ride on top of the load current peaks so that the two currents would add almost directly. This is the worst case because it draws the highest peak line current. For very high power factor loads of 80 to 90%, the magnetizing transient peaks tend to add to the load current in quadrature. This gives the least objectionable results because the line current peaks are lowest. The transient, however, becomes quite noticeable on an oscilloscope because it occurs when the load current is falling toward zero and separate peaks may be observed for considerably lower values of magnetizing transient. For the intermediate power factors of 40 to 70%, which are more common, the transient peaks occur about 20 to 40 deg past the peak of the load current wave. This condition is not as severe as the very low power factor condition and quite often a relatively large magnetizing current peak can be hidden in the trailing edge of the line current pulse without being very noticeable on an oscilloscope.

Other Conditions Contributing to Transients

There are other conditions which cause high magnetizing transients even when using a controller designed for proper initiation. Most of these result from incorrect settings of the time controls.

When the *squeeze time* is set too short, the load current needed to fire the ignitrons will not pass until the welder electrode tips close and make good contact with the work. Normal magnetizing current does not fire the tubes at the right time, and only one ignitron will usually fire. This produces extreme magnetizing transients continuing until the tips do close. When the tips finally close, they do so at random and then follows the apparently slow decay of the magnetizing transient. This situation is sometimes difficult to correct because of the difficulty of diagnosing the cause of the transient. There may be only a little fire when the tips close. It is difficult to tell the difference between this and the little fire observed from an inadequate *hold time*, scaly stock, or welding too close to the edge of the work. When transient trouble occurs, an early check should be made to insure that adequate *squeeze time* is allowed.

When the *hold time* setting is too short and the electrodes actually break the welding current, sparking will be observed at the tips, the electrodes may need frequent dressing and the welds may appear pock-marked. This has little effect upon the transformer, however, as long as the electrodes part at the end of the weld sequence and allow the residual flux in the transformer to decay.

If the *weld time* is too short, the weld heat may be insufficient but no significant transient problems will be encountered. When gaps in the welding current occur, which may be caused by hard-starting ignitrons, or by a control circuit which does not start each half cycle instantly after the current in the preceding half cycle ends, a high magnetizing transient begins to build up. The width of the gap determines the length of time before line fuses, circuit breakers, or other control equipment may be affected.

If the cause is a hard-starting ignitron, the transient peaks are conducted by the other ignitron. Figure 11 shows the primary welding current on hi-six tap with parallel secondaries. It was found that a 5-deg gap produced a noticeable transient, and a 10-deg gap

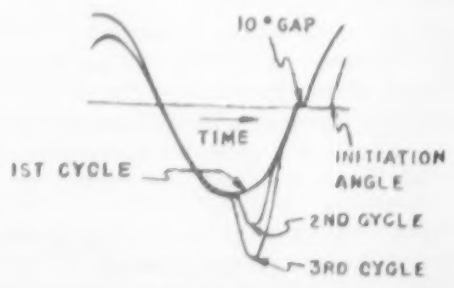

Fig. 11 Transient build-up due to hard-starting ignitron—3-cycle weld

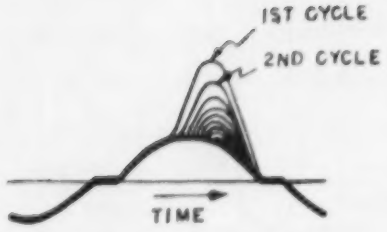

Fig. 12 *Transformer primary current showing effect of 70% heat—15-cycle weld*

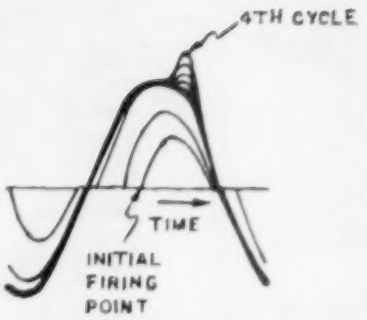

Fig. 13 *Transformer primary current showing effect of slope control on magnetizing transient—10-cycle weld, 100% final heat*

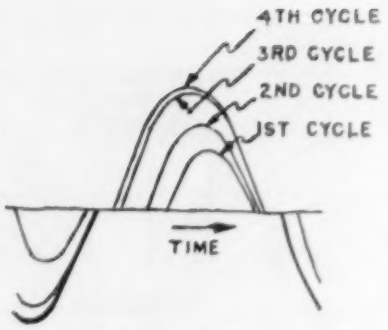

Fig. 14 *Transformer primary current showing effect of slope control on magnetizing transient—4-cycle weld, 80% weld heat*

produced a nearly two to one transient ratio. Again, opening of the electrode tips at the end of the weld will cause the residual flux to decay and the next weld may be initiated properly with a similar buildup of transient if the gap unbalance persists.

In the case of a pulsation weld, that is, when the tips do not open between *heat times*, the first *heat time* may be properly initiated with the following ones showing transients on the trail half cycles. This results from the current circulating in the secondary between welds which keeps the core magnetized in the trail direction, thus requiring an earlier start for all welds after the first. A steady-state condition is usually reached after 4 or 5 pulses. This can be avoided, of course, if the *cool time* is long enough to allow the circulating current to die out between pulses—a solution which is impractical, however, since a period of about 100 cycles is usually required for the circulating current to die out when the secondary circuit is closed.

A similar affect occurs when the discharge resistor is of a value below approximately 100 ohms on a 460-v installation. The circulating current may be biasing the transformer at the time the next weld is initiated. It is for this reason that this discharge resistor should be kept in excess of 100 ohms for hypersil welding transformer installations.

The Effects of Heat Control

An interesting side light is revealed when electronic heat control is used with hypersil welding transformers. Two general statements may be made.

1. No transients are experienced with heat settings equal to or lower than the setting corresponding to the proper initiation point for the first half cycle.
2. At higher heat settings, the magnetizing transient is found to occur rather strongly.

Figure 12 shows the primary current set to 70% on hi-six tap with parallel secondaries and 460 v impressed on the primary circuit. Note that this is a 15-cycle weld and that the transient takes some measurable time to die out.

This test and others indicate that the combination of a proper initiation point (or delayed firing) and heat control will give results far superior to those obtained when utilizing heat control only.

The use of a slope control will also give superior results. In this case a minimum *slope time* with a low initial heat setting is most effective. Refer to Fig. 13 showing the effect of a 3-cycle *slope time* with a 20% initial heat setting. The transient is limited now to less than $1^1/_2$ to 1, and for heat settings of 80% and below, the transient is no longer visible. Figure 14 shows the effect at an 80% final heat setting. It is to be noted that there is no noticeable transient appearing above the normal current group. This latter case involved a 4-cycle weld.

Conclusions

In conclusion, it may be stated that hypersil transformers can be used with success in welding applications with almost all types of control equipment commonly available. Magnetizing transients may be successfully predicted when the characteristics of the welding transformer are available and the power factor of the welding transformer itself will determine the optimum initiation angle. Control equipment can then be specified after a careful study of the requirements, thus permitting a sound economic selection to be made.

Acknowledgment

The author wishes to express his appreciation to C. W. Porter of the Square D Co., for his cooperation in the preparation of this paper.

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DISCUSSION BY CARTER SINCLAIR

Mr. Mierendorf's paper covers a subject which was independently investigated by the Specialty Control Department of the General Electric Co. This investigation, while less intensive than Mr. Mierendorf's, covered some other phases of the problem which may be of interest to this audience.

One phase of our investigation demonstrated that operation could be just as transient free with an odd number of half cycles as with an even number, providing the initiation point were shifted to the proper phase angle for this type of operation. The proper initiation point for odd-number-of-half-cycles operation was shown to be approximately 95°. This deviates from the 85° figure for full cycle operation. This would indicate that residual flux is the major factor in determining the deviation from 90° for the optimum firing point.

Our conclusion from this phase of the investigation was that for an 85° firing point, it is important to consistently obtain full cycles, or for a 95° firing point, an odd number of half cycles. The choice depends on economic consideration of the control elements involved.

Also included in our program was testing the combination of delayed firing and heat control in the range ahead of the delayed firing point. Results showed that while the earliest transient-free initiation point was not changed from that without heat control, initiation could be retarded after this point without introducing transients in the second half cycle if the heat were retarded below 100%. The farther the heat was retarded, the wider the transient-free zone became.

Carter Sinclair is associated with the Specialty Control Department of the General Electric Co.

Another area we investigated was seam and pulsation welding with hypersil transformers. The conclusion was that the initiation of impulses following the first impulse would be advanced to a point between the first initiation point and the power-factor angle of the welder. This point varies with cool time and would require a third initiation point. This is possible but it would be somewhat expensive and difficult to adjust. It would appear that Mr. Mierendorf's idea of using slope control would be one answer to the use of hypersil transformers on seam and pulsation welding. This application of slope control to pulsation welding would require that the slope control operate on each heat impulse individually, rather than sloping the entire weld interval which is now the NEMA standard.

The one statement by Mr. Mierendorf to which we take exception is his statement "The magnitude of all effects can be kept within bounds by using control equipment properly designed for the job." The hypersil transformer is very sensitive to overvoltage, and overvoltage frequently occurs on some plant systems at times of light load. The only way we know of keeping the transients within bounds on a transformer which does not have enough iron in it for the applied voltage is to deliberately set the full heat limit on the heat control so that balanced but discontinuous current is obtained at nominal 100% heat. This is, in reality, just not letting it reach full phase on, or 100% heat. The control cannot overcome any basic deficiency of iron, and this should be recognized by transformer designers and by users.

With this one exception our findings are entirely in accord with those of Mr. Mierendorf and we wish to congratulate him on the thorough tests he has run and the excellent presentation of his findings.

AUTHOR'S REPLY

The investigation cited by Mr. Sinclair concerning operation with odd number of half cycles and the provision for shifting the initiation point to 95° is of interest. We carried on similar tests with a 75-kva transformer. Our tests showed an insignificant residual flux, provided of course that the secondary circuit was open between spot welds and the primary discharge resistor was greater than 100 ohms. Therefore, no change was required in firing angle when compared to operation with full cycles of conduction. However, we can account for residual flux due to transformer design, use of a nonlinear discharge resistor or initiation of the succeeding spot weld without opening electrodes or allowing sufficient time between spot welds for the residual flux to decay. In any event, we believe that a fixed angle, such as 95°, would be valid only under certain specified conditions. It would seem more reasonable to believe that a number of possibilities existed dependent upon the aforementioned factors, similar to the range of firing angles mentioned in the paper when full cycle conduction occurs.

Mr. Sinclair indicates that their investigation of seam and pulsation welding required various initiation angles following the first impulse. We point out that residual flux is the cause, and that the primary discharge resistors are more effective in determining the residual flux decay time. Similar conditions apply to full or half cycle conduction with single spot welds only to a lesser degree since the secondary circuit is open between spot welds.

We agree wholeheartedly that a control cannot overcome deficiencies in the transformer. Reference to Fig. 5 of the paper illustrates this situation. Notice that magnetizing current peaks are visible on both polarities. This effect should be noted by transformer designers since it indicates that the transformer does not have enough iron for the applied voltage.

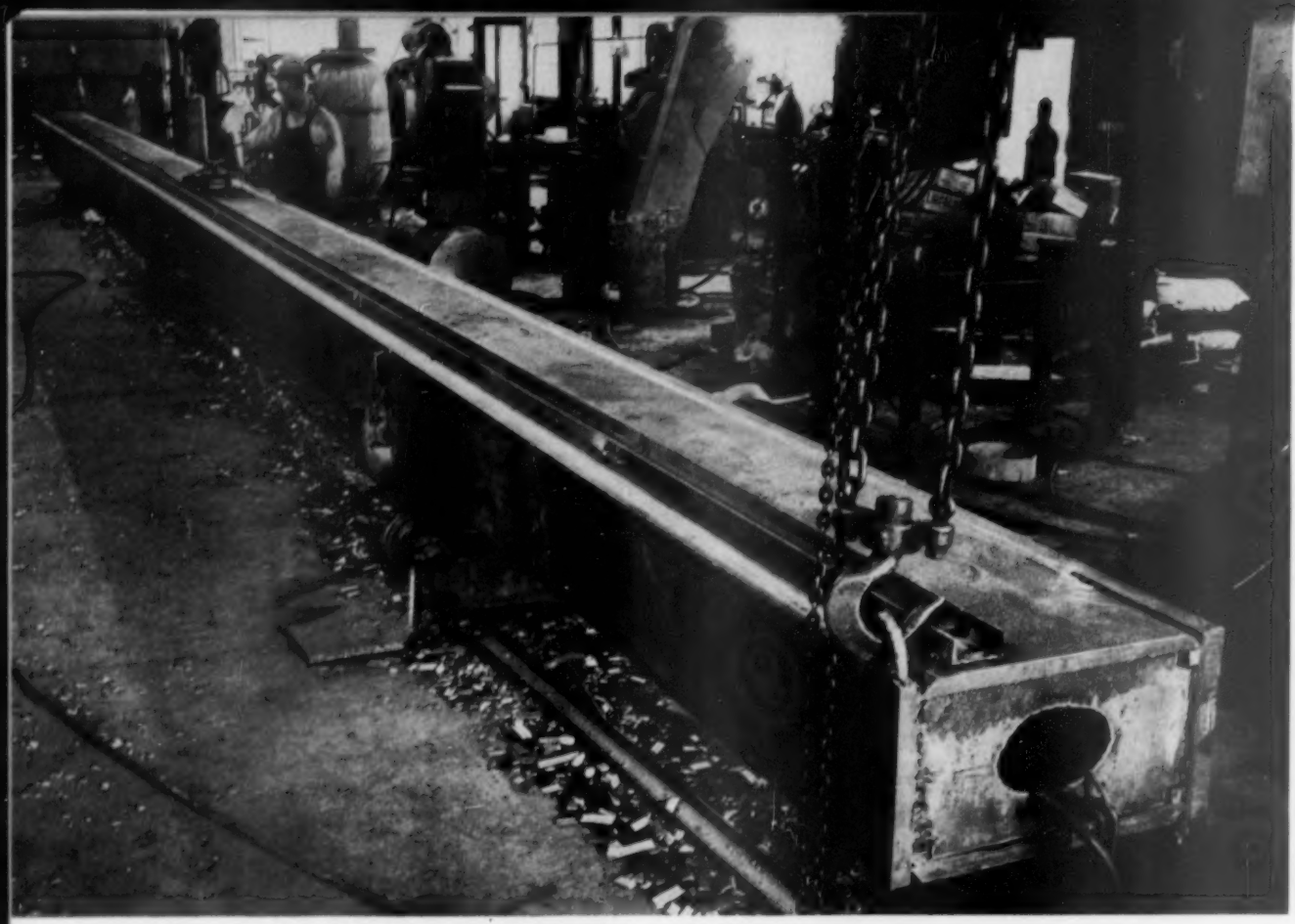


Fig. 1 Semi-automatic equipment using alloy flux welds this dipper stick made of T-1 steel

A NEW APPROACH TO THE AUTOMATIC WELDING OF ALLOY STEELS

Automatic and semi-automatic processes can be economically applied to the welding of the alloy steels now in use, particularly those of heavy thickness

BY EMMETT SMITH AND PAUL JERABEK

Emmett Smith is Chief Engineer, Electrode Division, and **Paul Jerabek** is Development Engineer, Lincoln Electric Co., Cleveland, Ohio.

Presented at AWS 1955 National Fall Meeting held in Philadelphia, Pa., Oct., 17–21.

During the past few years, there has been a large increase in use of low-alloy-steel welded structures. These steels are in a class containing up to approximately 6% total alloy and are used for a large variety of applications including pressure vessels, power piping, machinery, and chemical and refinery equipment.

Hand welding has been the usual method of fabrication, using hand electrodes which produce weld deposits with the proper alloy composition. With the increasing amount of alloy steel being welded and with the gradual increase in plate thickness of the weldments, many applications can economically use automatic or semi-automatic welding equipment.

The use of automatic welding equipment presents several problems. A single fabricating shop may weld a large variety of alloy steels. For a particular job,

only a small amount of electrode may be required and it becomes a problem to find the proper composition in the right wire size and the right coil size. In some cases, the composition required is not available in the form of wire and would have to be rolled special by the mill. In some cases, good welding practice requires the weld composition to be different than the plate composition. Such an electrode may have to be made of steel from a special heat.

The same problems are present with hand-welding electrodes, but these problems are solved largely by designing electrodes with mild-steel core wire and adding the alloys to the flux coating. During welding, the alloys are transferred from the flux to the weld metal, resulting in an alloy-steel weld deposit. By using a mild-steel core wire and adding alloys in varying amount to the flux coating, an infinite number of weld metal compositions are possible.

Alloy Fluxes Compounded to Specific Requirements

Basically this same method is now applied to submerged-arc automatic welding of alloy steels. A mild-steel electrode is used with an agglomerated alloy flux. Actually, the alloy flux is a mixture of primary fluxes, each primary flux containing one alloying element and the mixture compounded to meet the requirements of the particular application. The following primary alloy fluxes can be blended to weld most of the low-alloy steel applications: Chromium flux, molybdenum flux, vanadium flux and nickel flux.

Each primary flux is made by agglomerating the alloy with the fluxing materials. An additional primary flux, made of the same fluxing materials but containing no alloy, is used for adjusting formulas.

All of the primary fluxes are screened to the same size, they all have the same physical shape, and they are all very near the same specific gravity so that, after blending, there is no segregation. Any combination of the primary fluxes can be blended to make an alloy flux. The great flexibility and economy of this system becomes apparent when one considers that, with a stock of only five fluxes, it becomes possible to prepare an almost infinite number of alloy combinations. These alloy fluxes can be compounded and blended by the user, but usually the supplier does the compounding and blending.

Standardized Procedures Control Flux-Electrode Ratio

In order to maintain a consistent weld deposit composition, it is necessary to maintain a consistent ratio between the flux melted and the electrode melted. Hand-welding electrodes inherently maintain this ratio since the amount of coating melted is proportional to the amount of electrode consumed. In automatic welding, this ratio is controlled by welding procedure.

It is possible to compound an alloy flux for almost any procedure, but it is more satisfactory to standardize on procedures and, thereby, reduce the number of flux compositions. Procedures given in Fig. 2 have been established by experiment. A consistent weld metal composition will result when using any point on the various curves. For example, a consistent alloy-weld deposit will be obtained with $^{1}/_{8}$-in. electrode at 550 amp and 29 v or $^{5}/_{32}$-in. electrode at 700 amp and 32 v or $^{3}/_{16}$-in. electrode at 650 amp and 28 v.

Figure 3 shows the application to specific joints of the procedures in Fig. 2.

Each alloy steel application must be studied separately to determine the proper weld metal composition to meet the specific service requirements.

Application to Match Base Metal Composition

Some alloy applications require the weld deposit to be the same composition as the base metal. The chromium-molybdenum steels for elevated temperature service are a good example of this class of steels.

This category embraces a very large number of steel compositions, increasing in alloy content as the service temperature or operating stresses are increased.

Chromium from 0.5 to 5.0% is added mainly for its effect on resistance to oxidation and corrosion, but it also contributes in some degree to creep resistance. It

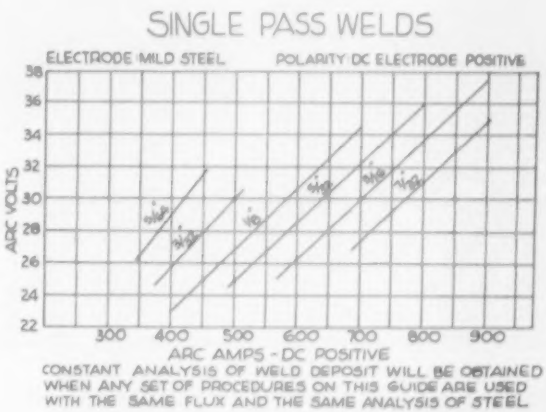


Fig. 2 Standardized procedures for giving consistent results with alloy fluxes

Plate		Electrode	Amperes	Volts	Speed Inches/min.
	(1)	5/32	550	27	24
	(2)	5/32	630	30	24
	(1)	5/32	550	27	20
	(2)	5/32	700	32	16
	(1)	3/16	700	30	22
	(2)	3/16	850	35	16

Welding Procedures for Butt Welds

Fig. 3 Application of standardized procedures to specific joints

Table 1—Physical Properties of Chromium-Molybdenum Weld Metal

Chemistry of weld deposit, %				Stress relieve temperature, °F	Tensile, psi	Yield point, psi	Elongation in 2 in., %
Cr	Mo	Mn	Si				
0.67	0.58	0.89	0.41	1350	73,000	52,500	28.5
1.10	0.58	0.90	0.40	1350	72,400	52,000	29.0
2.20	1.00	0.95	0.40	1350	79,000	58,600	28.0
5.10	0.50	1.0	0.70	1375	85,000	65,000	25.5
5.10	0.50	1.0	0.70	Annealed	67,400	37,400	35.0

is also added to the plate as insurance against graphitization under elevated temperature service. Graphitization has not been a problem in weld metal.

Molybdenum is added for its effect on resistance to creep. The amount added is usually from $^1/_2$ to 1%. On rare occasions, vanadium is added for the same purpose.

Silicon finds a use in some grades of chromium-molybdenum steel. The purpose of silicon additions is similar to that of chromium—to increase the resistance to oxidation. The high silicon grades are welded with standard compositions of chromium-molybdenum fluxes, the chromium sometimes being increased to compensate for the lower silicon content in the weld.

Carbon content is normally limited to 0.20% or less, the higher alloy grades usually being limited to a lower carbon content. High carbon content will give rise to cracking problems in welding. Welds made with alloy fluxes will rarely exceed 0.10% carbon.

Manganese limits on chromium-molybdenum grades are sometimes as low as 0.60% for reasons other than welding. This situation parallels the case of mild steel where AISI 1020 is limited to 0.60% Mn. The highest quality multiple pass welds made in this steel by the submerged-arc process will rarely be under 0.80% Mn and often over 1%. These manganese contents are accepted without question, since manganese in this range is desirable from the standpoint of physical properties and resistance to cracking. Manganese in this range is also desirable in chromium-molybdenum weld metal.

The physical properties for weld metal produced with alloy flux and mild-steel electrode is given in Table 1.

Figure 4 is a cross section of a welded joint in a special composition plate. The weld metal analysis is uniform from top to bottom.

Table 2—Properties of Weld Metal in T-1 Steel

	Tensile, psi	Yield point, psi	Elongation in 2 in., %
As-welded	118,700	106,700	17.5
Stress-relieved	114,000	98,000	19.5

	C	Mn	Si	Ni	Cr	Mo
	%					
Plate	0.138	0.88	0.23	0.87	0.60	0.38
Weld metal	0.072	0.99	0.45	1.96	1.10	0.50

Application to Heat-Treated Base Metal

Alloy steels of another classification are those which are heat treated before welding and are put into service after welding without any heat treatment other than stress relieving. T-1 steel is an example of this class.

To match the physical properties of the plate, the weld metal must develop a minimum yield point of 90,000 psi and a minimum tensile strength of 105,000 psi, and have good impact properties at low temperatures in both the as-welded and stress-relieved conditions. The weld metal is alloyed to meet these mechanical properties rather than duplicate the chemistry of the plate.

It is good welding practice to keep the carbon content of the weld metal less than 0.10% and it is, therefore, necessary to add sufficient alloy to develop the required yield point and tensile strength. Chromium and molybdenum are added for this purpose. In order to develop good impact properties at low temperature, nickel is added. A typical analysis of weld metal in T-1 steel is carbon, 0.08%; chromium, 1.3%; molybdenum, 0.6%; nickel, 2.0%; manganese, 0.90%; and silicon, 0.4%. This composition is easily obtained with alloy flux and mild-steel electrode. Typical physical properties are given in Table 2.

Charpy keyhole notch transition temperatures as determined by split values or 15 ft-lb minimum are −175° F for as-welded specimens and −125° F for stress relieved. Room temperature values are 20 to 27 ft-lb as welded or stress relieved.

A specific application of welding T-1 steel with alloy flux is shown in Fig. 1. This is a dipper stick made of T-1 plate, $1^1/_4$ to 2 in. thick, and the over-all length is 65 ft. The plates are torch cut and assembled by tack welding. The joints are then welded with an alloy flux and mild-steel electrode using semi-automatic equipment. The welding gun has been mounted on a self-propelled unit which makes the operation virtually automatic.

Application to Base Metal Heat Treated After Welding

Another broad class of alloy steel includes those steels which are given a complete heat treatment after welding. An example of this class is AISI 4130 which is heat treated after welding to a tensile strength of 180,000 psi.

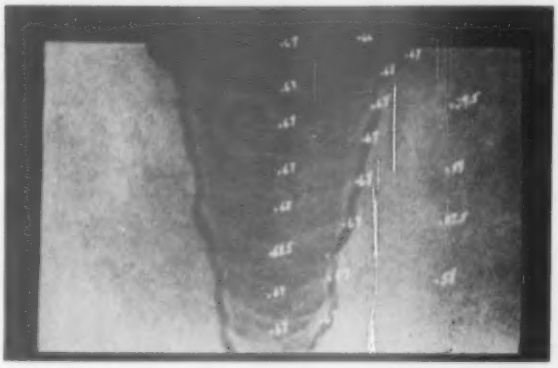
The problem of welding this steel has been approached in many ways, but one successful approach is the use of

an alloy flux with low-carbon electrode. Carbon in the weld is kept lower than in the plate to avoid weld cracking. To compensate for the lower carbon content, the alloy content of the weld is increased above the 4130 specification. The resulting weld has a higher critical temperature than the plate and the quenching operation requires a temperature of about 1600° F. This is followed by a tempering operation at about 850° F, resulting in a tensile strength in both plate and weld of 180,000 psi.

Application with Alloy Electrode

All of these applications use a mild-steel electrode. Another field of application for alloy flux is where alloy electrode is used. An overlay of alloy steel, such as stainless steel, on a small area of a weldment or steel casting can avoid the expense of making the entire piece of stainless steel. A single layer of weld deposit using a stainless-steel electrode may result in enough dilution by the base metal to make the overlay useless for the service requirements. An alloy flux can add sufficient alloy to the deposit to compensate for the dilution. Another application uses a standard stainless-steel electrode and adds molybdenum to the deposit from the alloy flux to resist special conditions of corrosion and erosion.

Many new possibilities are now opened by using alloy fluxes with mild-steel electrodes or modifying weld deposits where standard available electrode compositions are used. Many of the advantages gained by using automatic welding on mild-steel weldments can now be obtained on low-alloy steel weldments.



As welded — Rockwell A

Butt Weld in 3 inch Alloy Steel
Hardness numbers are Rockwell A

	C .	Mn	Si	Cr	Mo
Plate	.18-.23	.40-.70	.40-.60	.45-.65	.90-1.1
Weld-Top	.18	.73	.42	1.15	1.05
Weld-Center	.16	.73	.43	1.15	.94
Weld-Bottom	.17	.74	.42	1.12	.90

Fig. 4 A close check of this welded joint in special composition plate shows uniform weld metal analysis

The Welding Journal provides the most complete library of information on the art and science of welding available . . . anywhere. If you have a product for the welding or allied industries, the Journal's pages will reach your market.

TWO MILLION POUNDS OF WELD METAL USED IN FABRICATION OF U.S.S. FORRESTAL

BY J. B. DAVENPORT AND L. M. WOOD

Building the U.S.S. *Forrestal*, the first in the class of the largest and most powerful ships ever designed, was a pioneer effort for one of the most experienced shipbuilders in America, the Newport News Shipbuilding and Dry Dock Co.

Greatest Engineering Enterprise

The sheer bulk of the *Forrestal* all but numbs the imagination of one seeing her for the first time. From a distance the easy, tapering lines of the immense hull camouflage her true size. A close view brings her great dimensions into proportion. Her keel is 45 ft. below sea level and the flaring stem curves 97 ft into the sky above the keel. The hangar deck, where planes are stored, is the length of 2½ full-size football fields. The total area of her flight deck is nearly four acres.

Her 1039-ft length and 252-ft width make her longer and wider than any naval vessel afloat. If the Empire State Building could be laid alongside the ship, the giant propellers would brush the spire atop the building tower.

J. B. Davenport is Manager and L. M. Wood is Technical Sales Representative, Charlotte District, Air Reduction Sales Co.

Fastest Carrier

The *Forrestal's* keel was laid on July 15, 1952, and she was commissioned for active duty Oct. 1, 1955. This mobile sea base with a complement of more than 100 jet-powered planes will be able to deliver the atomic bomb to targets far beyond the reach of earlier carrier-based aircraft. The ship's cruising radius is comparable to those of the *Midway* and *Essex* class carriers. However, the design was modified to permit easy refueling at sea. Her great speed, nearly 40 statute miles per hour, will provide an element of surprise in attack as well as an element of safety in outrunning attackers.

Compartmentation a Feature

Carrier experience in the Pacific, during World War II, showed that ships with many bulkheaded compartments below could control damage to an astonishing degree. The hull compartments prevent the spread of fire and help contain the effect of a torpedo in, say, the port side. It can be neutralized by flooding a starboard compartment. The ship can thus be kept on an even keel, able to handle her planes.

Fig. 1 The U.S.S. *Forrestal* on her sea trials

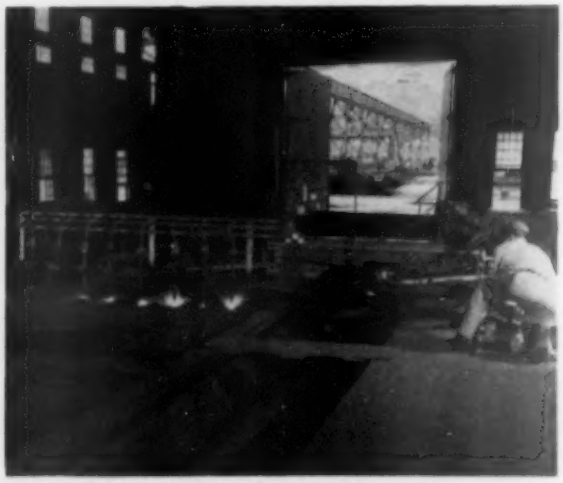


Fig. 2 Pantograph-type flame-cutting machine equipped with electronic tracer being used in Newport News Shipbuilding fabrication shop

Fig. 3 Subassemblies for the *Forrestal* being arc welded; twelve different kinds of steel were used

Fig. 4 Arc-welding job being performed on *Forrestal* hangar deck; opening in side of ship is for aircraft elevator

The *Forrestal* is compartmented as no other ship ever built. The vital machinery spaces are distributed so as to minimize disablement due to enemy attack. From her bottom up are lengthwise "torpedo defense bulkheads," or inner hulls, which give her unprecedented protection against torpedo attack. In all, the *Forrestal* has 1240 water-tight compartments.

Statistics Incredible

Statistics concerning this giant of the seas are incredible. It took 700 draftsmen and engineers more than a year to produce the blueprints for her construction. The crew of 3500 officers and men will live and work in air-conditioned quarters made possible by seven air-conditioning units of 500 tons capacity each.

Because the size and weight of everything connected with the ship is greater than in previous vessels, every item of equipment had to be designed especially for the job. Take the anchor chain. Since the ship's estimated weight of 59,900 tons in the standard condition and over 70,000 fully loaded would snap any chain ever cast, engineers designed a special chain. It was 2160 ft long and weighed 246 tons. Each link is $28^1/_2$ in. long by $17^1/_4$ in. wide and weighs 360 lb. Breaking strain: 2,500,000 lb.

Or, take shipboard arresters. They had to be powerful enough to bring the heavy, high-speed jet planes to a stop in a short distance. Arresters will stop today's 70,000-lb jets 150 ft after they hit the deck at better than 100 mph.

2400 Miles of Weld Metal

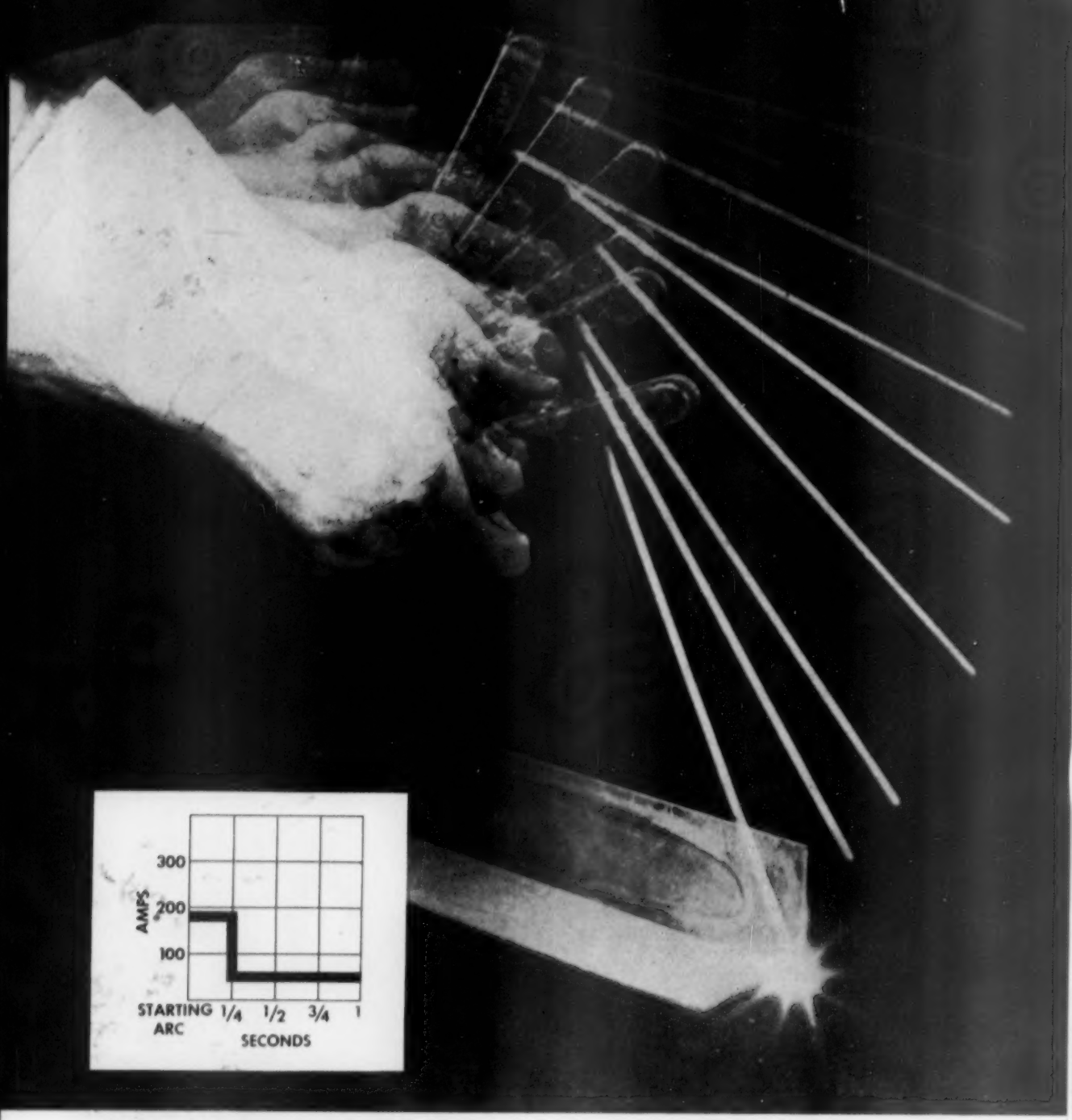
Almost 52,000 tons of steel, twelve different kinds, were used in the construction of this great ship. This steel—plus aluminum, copper and many other metals—required 2,000,000 lb of weld metal, enough to make a weld $^1/_4$ in. wide and 2400 miles long—the distance

Fig. 5 Head-on view of the *Forrestal*—weld seams everywhere

across the United States from the east coast to the west coast. From the 180 miles of piping to the almost four acres of flight deck the familiar seam of weld metal is always in evidence.

The ever-growing importance of welding and cutting is well demonstrated aboard the mighty *Forrestal*. A million-and-one fabrication jobs were accomplished with the help of oxyacetylene flame-cutting machines and electric welding equipment and supplies.

Figures 1 through 5 give some idea of the part played by welding and cutting products and processes in bringing off this gigantic enterprise.



NO FALSE STARTING, no ragged weld beginnings with the G-E a-c welder's hot-start. Automatic G-E hot-start gives an extra boost of current for ¼ second . . . assures instant arc striking and extra penetration at the start of the weld.

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NEW 200-AMP engine-drive welder, field-proven on construction and job-shop work, gives steady output, even above full load.

No False Starts . . . No "Popouts" With New G-E Line of AC Welders

Arc strikes instantly, stays steady—gives a sound weld from start to finish

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General Electric's new line of a-c transformer welders gives you this good arc—instant-striking and steady—plus many other features that make your welding faster, easier, and more economical.

1. NO FALSE STARTS. G-E automatic hot start provides that necessary extra surge of current which assures you of instant arc striking. Besides saving time, the hot-start furnishes extra penetration at the start of the weld—and reduces sticking.

2. ARCS ARE EASIER TO HANDLE, too. Popouts are practically eliminated because G.E. has made the normally stable a-c arc even more stable by the addition of special capacitors. These capacitors provide the equivalent of 5 additional open-circuit volts.

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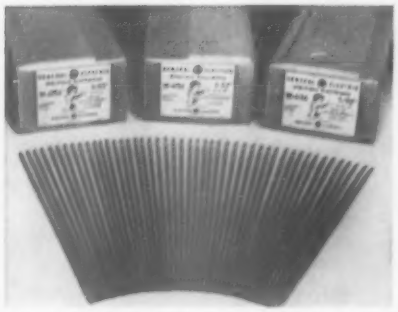

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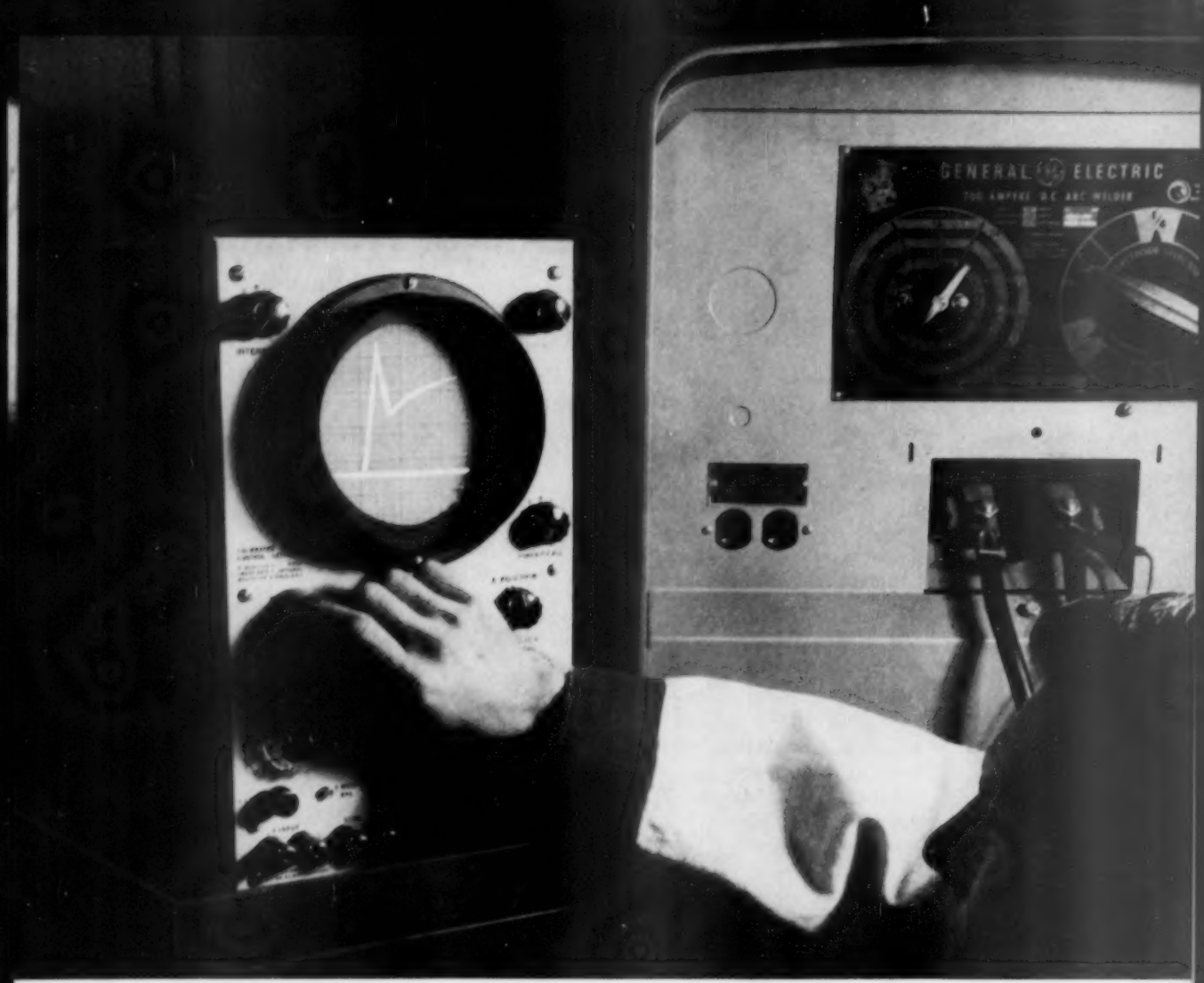

G.E.'S NEW ENGINE-DRIVE WELDER GIVES YOU . . .

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If you're using more than a 200-amp engine-drive welder for light to medium-heavy construction, you may be losing money. You may be paying for inefficiency—compensating for excessive loss of amperage and arc heat when operating at full load for sustained periods.

Now, with G.E.'s new 200-amp engine-drive welder, it's not necessary to buy more expensive, higher rated machines for pipeline, light construction, or job-shop work. This field-tested welder gives you steady output and 100% arc stability, hour-after-hour, even when operated ***above*** full load.

Test this powerful new welder yourself, and see the many advanced design features—new slow-down control, extra-rugged construction, and many others. Contact your nearby G-E Welding Distributor today. He's listed in the yellow pages of your phone book. Section 714-3, General Electric Co., Schenectady 5, New York.

EXTRA-STURDY construction is shown in this demonstration. Five nickels stand on edge while welder is operated at full load.

GENERAL ELECTRIC

Fig. 1 This submerged-arc-welded front-end loader frame has a lift capacity of 2000 lb. Six other attachments in addition to the utility bucket illustrated can be used on it

Fig. 2 A lift arm being submerged-arc welded of 7-gage mild steel, in one pass, at an average welding speed of 45 ipm.

SUBMERGED-ARC-WELDED FRONT-END LOADER PROVES STRONG, EFFICIENT

A combination of sturdy design, excellent fabrication, and efficient performance best describes the Davis hydraulic tractor loader, built by the Mid-Western Industries Incorporated, Wichita, Kan. The loader lift arms, which are submerged-arc welded of 7 gage mild steel, can take any one of seven attachments and thereby gives light tractors a wide range of job applications. A four-point mounting design permits fast, easy hookup and removal of the lift arms and ram shafts, so that a tractor can quickly be made ready for several types of work. This flexible front-end loader has a lift capacity of 2000 pounds.

The loader lift arms and permanently mounted rear sill are submerged-arc welded at an average speed of 45 ipm. As shown in Figs. 1 to 4, press-formed U-shapes are clamped in a quick operating compressed air jig to form a box-type frame unit. Submerged arc welding joins the adjacent edges of the pieces in one pass. Two jigs operate in tandem so that welding operations are continuous. As the submerged-arc welding machine completes a weld on one frame, it moves on to the next. The operator, meantime, removes the finished part and sets up another fraime arm to be welded. This same jigging and welding procedure is followed in fabricating the rear sill.

The submerged-arc welding process employs a blanket of granulated material to protect the weld zone from the atmosphere. Operations are fast and without sparks or glare. All of these submerged-arc welds are of the highest quality, and require no post-weld treatment.

Based on a story by the Linde Air Products Co., New York, N. Y.

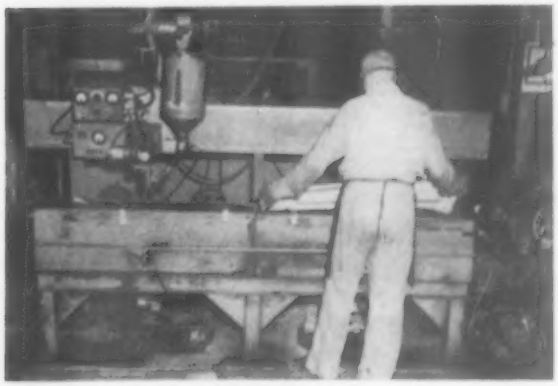

Fig. 3 While one jig is unloaded and reloaded (right), the automatic submerged-arc welding machine welds the unit clamped in the second jig (left)

Fig. 4 Lift arms ready for paint spray. The four-point mounting design permits fast, easy hookup and removal of the lift arms and ram shafts

Society News

Important Innovations to Be Featured in Buffalo During Week of May 7th

Many important innovations will highlight the coming sessions in Buffalo, N. Y., this May, when the AWS stages its twin events, the 1956 National Spring Meeting and the Welding Show. Current indications are that these sessions will bring the largest turnout of members and visitors ever to attend a Society function.

High on the list of special events is the first joint sponsorship of four technical sessions by the Metals Engineering Division of the American Society of Mechanical Engineers. This great pioneering move is expected to focus more engineering attention on the Society's meeting than ever before. Papers of common interest to both groups will be featured at these sessions.

Welding conferences will be held as part of the Welding Show. These conferences were tried last year in Kansas City with so much success that they will now be expanded and made an outstanding fixture. The emphasis at the Conferences will be on the practical rather than on the research aspects of welding.

The Conferences will be held at the Memorial Auditorium, where the exhibits are displayed, and no registration fee will be required. Topics of broad, general interest will be discussed. The primary purpose of these sessions will be to provide a forum for those who are not vitally concerned with research problems, but do have a great interest in keeping abreast with the day-to-day progress in welding as it affects the metal working plant.

The AWS Technical Activities Committee will sponsor another of its eventful sessions at the Spring Meeting. They have chosen as its principal topic the matter of safety, health and fire prevention. Few who come to Buffalo can afford to miss these talks.

On a more specialized level, but of outstanding significance, will be a session on the welding of nuclear reactor components. Here, too, the innovation will bring in the participation of an outside group. In this case, the Welding Committee of the Atomic Energy Commission will co-sponsor with the Society papers dealing with the important subject of nuclear energy.

Although these four attractions are expected to capture a good deal of visitor interest, they are by no means the only outstanding aspects of the meeting. A few of the other highlights are:

- The largest Welding Show ever staged. More exhibits, more demonstrations, more experts, bigger booths.
- The first time that new national officers will be elected in the Spring. The Society's Annual Meeting will take place in Buffalo.
- An Educational Lecture Series for students in the engineering field.
- The President's Reception, the outstanding social event of the welding year.
- Plant tours of prominent factories in the Niagara Frontier area.
- The National Dinner with a gala cast of entertainers.
- Ladies' Entertainment with a full program for the ladies.
- Opportunity for visiting Niagara Falls, one of the seven natural wonders of the world.

Members and visitors are reminded by AWS headquarters that room assignments will be started in March; those wishing choice accommodations should write early for their requirements. Travel facilities to and from Buffalo also are likely to be taxed during the week of May 7th and many may find it desirable to make direct reservations with airlines, railroads and busses well in advance.

Because of the wide variety of interests which can be served at the Show and Spring Meeting, company executives are being urged to send their large "teams" to Buffalo this year. Younger men, particularly, will derive great benefit from being able to attend technical sessions, hear conference reports on practical welding, visit plants with outstanding welding installations, and see the latest in welding equipment at the show.

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SCENE OF FOURTH WELDING SHOW

This is the Buffalo Memorial Auditorium where the Fourth AWS Welding Show will be held on May 9–11. Some 100 exhibitors will participate

Welding Distributors Become AWS Supporting Members

Two prominent welding distributors have recently become Supporting Members of the AMERICAN WELDING SOCIETY.

The first of these is O.K.I. Welding Supply Co. of Cincinnati, Ohio. E. C. Caluwaert is its president.

The second is the Johnson Welding Equipment Co., Inc., 3421 West Balmont Ave., Chicago 18, Ill. William F. Johnson is its president.

North American Aviation Now a Sustaining Member of AWS

North American Aviation is one of the latest organizations which have become sustaining members of the American Welding Society.

North American Aviation's Missile and Control Equipment Operations (MACE) is engaged in research and development in connection with the Air Force's SM-64 Navaho missile program.

Missile airframe and related work is being performed by the Missile Development Division. The Autonetics Division is in research and development of missile guidance and control equipment as well as development and manufacture of fire and flight control systems for jet aircraft.

The MACE organization also embraces the Rocketdyne Division, which performs research, development, and manufacture of some of the world's largest thrust rocket engines. MACE is an important part of North American Aviation, designer and manufacturer of the F-100 Super Sabre series for the Air Force—producer of more airplanes than any other company in the world.

A. T. Mocium has been designated by North American Aviation as the official Sustaining Member Representative.

Weld Design Clinic to Be Held by Dayton Section

The Dayton Section will hold its second annual "Weld Design Clinic" at the Albert Emmanuel Library Auditorium, University of Dayton, on the 4th of April 1956. This one day clinic will be a continuation of the previous year's clinic. Professor Roy B. McCauley of Ohio State University will be chairman of all three sessions. The subjects to be discussed will be as follows:

A. Analytical design of welded joints
   (a) Stress analysis in beams, static loads, ultimate and yield point stresses, dynamic loads, stress distribution
   (b) General considerations for designing a joint; rigid, semi-rigid, and simple support
   (c) Examples of connections in parts and structures
B. Analysis of a simple pinned truss
C. Fundamentals of rigid frame (indeterminate) design, stiffness and carry-over factors, distribution of stress
D. Questions on subject matter

Additional information may be had by contacting G. O. Williams, Hobart Brothers, Troy, Ohio.

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Airco #4 High Tensile Welding Rod. Whenever current codes and product specifications allow the use of a lower priced, high strength rod, Airco #4 will meet all specifications. This rod is for producing welds in low alloy steel requiring minimum tensile requirements of 62,000 psi.

Airco #7 Mild Steel Rod. This low priced general purpose welding rod is popular in job shop and maintenance work for welding low carbon steel. In using this rod it is suggested that the weld metal pool be worked so as to include a fair amount of base metal in the mixture.

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Section News and Events

as reported to Catherine O'Leary

SOCIAL MEETING

Albuquerque, N. Mex.—A purely social function for the members, wives and friends of the *Albuquerque* Section was held on January 17, 1956 in Lobo Joe's Dining Room with an attendance of 75. After cocktails, a very nice buffet-style supper was thoroughly enjoyed. Many of the members enjoyed dancing while others renewed old acquaintances. The meeting was a huge success.

PRECISION GAS CUTTING

Albuquerque, N. Mex.—The regular monthly meeting of the *Albuquerque* Section was held on January 20th in the Industrial Arts Building of the University of New Mexico. Speaker was Harry A. Huff, [illegible], of the Air Reduction Sales Co., New York, who discussed briefly the possibilities of gas cutting, the comparative efficiency and costs of gases used in combination with oxygen, along with some humorous anecdotes of his varied career in this field. The Air Reduction film "Burning Blades" was shown, followed by several slides showing the mechanics and working principles of various machines in the film.

The group then went to the laboratory, where equipment had been set up, and witnessed a live demonstration of several units. Many questions were asked, showing considerable interest in the possibilities of the field. Sixty members and guests were present.

FILMS

Birmingham, Ala.—Two very interesting films were shown by R. A. Davis, [illegible], engineer for the Chicago Bridge & Iron Co., Birmingham, at the January 10th meeting of the *Birmingham* Section held at Hooper's Cafe.

The first film, a short, entitled "Operation T-1," showed the rather spectacular testing to destruction of a series of pressure vessels made of a new "miracle" steel. The second, entitled "The Big Sphere," shows the sequence of erection of the world's largest pressure vessel, a 225 ft diam Hortonsphere for the Knolls Atomic Power Laboratory. This sphere housed the trial run on the Nuclear Reactor for the Atomic Submarine, Sea Wolf.

X-RAY EQUIPMENT

Shelton, Conn.—Fred C. Sarchet of the Balteau Electric Corp., Stamford, Conn., was the speaker at the January 19th dinner meeting of the *Bridgeport* Section held at Rapps Restaurant in Shelton. His subject was "X-ray Equipment."

WELDED PRESSURE VESSEL

Chicago, Ill.—Seventy-eight members and guests of the *Chicago* Section were present at dinner on November 18th at Burke's Restaurant. After dinner, the gathering enjoyed live entertainment given by the Illinois Bell Telephone Co. under the title of "The Man on My Line." Some 115 members and guests were present at the technical meeting which followed in the Auditorium of the Peoples Gas

SECTION MEETING CALENDAR

MARCH 22

NIAGARA FRONTIER Section. Dinner at 6:45 P.M. LaSalle Yacht Club, Niagara Falls, N. Y. "Experiences During Government Sponsored Trip to 14 European Countries, with Pictures," by Clarence E. Jackson, Metals Research Laboratories.

APRIL 9

NORTHWEST Section. 6:30 P.M. Covered Wagon, Minneapolis, Minn. "Design and Construction of Elevated Water Tanks," by Christian Arne, Research Engineer, Chicago Bridge and Iron Co.

APRIL 10

DAYTON Section. 8:00 P.M. Dayton Engineers Club, 112 E. Monument Ave., Dayton, Ohio. "Hard Facing," by Howard S. Avery, Research Metallurgist, American Brake Shoe Co.

OKLAHOMA CITY Section. "Inert Gas Cutting Processes," by G. R. Clay, Linde Air Products Co.

APRIL 12

IOWA-ILLINOIS Section. 7:30 P.M. American Legion Club, Moline, Ill. "Resistance Welding Controls and Their Functions," by J. W. Brown, Square D Co.

NORTHERN NEW YORK Section. Stanley Club, Pittsfield, Mass. "The Welding of Plastics," by Dr. J. A. Neuman, American Agile Corp.

SAGINAW VALLEY Section. Dinner meeting at High Life Inn, Saginaw, Mich. 7:15 P.M. (Tentative) "Use of Electronic Controls on Machine Sequencing of Resistance Welding Equipment."

APRIL 13

DETROIT Section. Quiz the Experts.

APRIL 16

ROCHESTER Section. "What's New in Resistance Welding Equipment."

APRIL 17

HARTFORD Section. Annual plant visit, Wallingford Steel Co., Wallingford, Conn. Dinner at Oakdale Tavern on Yankee Silversmith.

APRIL 18

SOUTH FLORIDA Section, Miami, Fla. "Power Sources," by G. K. Willecke, Miller Electric Mfg. Co., Inc., Appleton, Wis.

APRIL 20

FOX VALLEY Section. Appleton Elks, Wisconsin. 8:00 P.M. "Hard Surfacing Electrodes," by L. J. Sandowski, Stoody Company.

MARYLAND Section. Engineers Club, 6 W. Fayette St., Baltimore, Md. "Welding in the Aircraft Industry," by Mr. Wood, Glenn L. Martin Co.

MILWAUKEE Section. "Submerged Arc Welding," by N. G. Schreiner, Linde Air Products Co.

APRIL 21

NORTH CENTRAL OHIO Section. Second Annual Ladies Night. Mansfield, Ohio.

APRIL 24

NORTHWESTERN PENNSYLVANIA Section. Plant visitation, Bucyrus-Erie.

APRIL 26

MADISON, WIS. Section. "The Value of Non-Destructive Testing in Welding," by R. O. Schiebel, Jr., Magnaflux Corp.

APRIL 27

PITTSBURGH Section. Georgian Room, Webster Hall Hotel. Nineteenth Annual Tri-State Ladies Night and Dinner. Entertainment, door prizes, music, guest speaker.

Editor's Note: Notices to be published in any one given issue must reach Journal office prior to the first of the preceding month. Give full information concerning time, place, topic and speaker for meeting.

ALBUQUERQUE HEARS TALK ON GAS CUTTING

Attendees gathered in Laboratory at University of New Mexico to witness gas cutting demonstration. Harry A. Huff, guest speaker, is shown at extreme left

Light & Coke Co. Elmer C. Korten, AWS, of the Hardford Steam Boiler Inspection & Insurance Co. spoke on "Inspection of Welded Pressure Vessels."

POSITIONING FOR WELDING

Chicago, Ill.—The *Chicago* Section held a meeting on January 20th dealing with the subject of positioning of welding. This subject was covered by Anthony Pandjiris, AWS, president of the Pandjiris Weldment Co.

The meeting was attended by approximately 125 people and was enjoyed immensely by all because of the highly descriptive manner in which this subject was presented. A pre-meeting movie entitled "The Jet's Story" which was presented by the General Electric Co. proved to be very interesting to all present.

EDUCATIONAL SERIES

Cleveland, Ohio—The Educational Committee of the *Cleveland* Section announces that the 1956 educational series began on Thursday, February 2nd at the Manger Hotel, and will be held on each Thursday evening for 8 consecutive weeks, ending with a dinner meeting on March 22nd. The speaker for this dinner meeting will talk on the subject "So You Want an Atomic Weldment Contract."

FUTURE FOR WELDING

Cleveland, Ohio—"The Future for Welding" was discussed in detail by James F. Lincoln, chairman of the Board, Lincoln Electric Company, at the *Cleveland* Section's January 11th Executives' Night Meeting held at the Manger Hotel. A well-informed and dynamic speaker, Mr. Lincoln's message proved to be of unusual interest and value to all parties concerned, and particularly to Cleveland area industrial leaders who were the guests at the meeting. This was truly one of the highlights of the Cleveland Section's activities for 1955–56.

A huge crowd of approximately 480 members and distinguished guests were in attendance. Included among these were AWS President Joseph H. Humberstone and AWS National Secretary Joseph G. Magrath.

In the course of his talk, Mr. Lincoln mentioned that 25 million tons of arc-welding electrodes and 100,000

WELDING'S FUTURE DISCUSSED BY LINCOLN BEFORE CLEVELAND SECTION

Shown at the speaker's table are (left to right) Art Portz; J. H. Humberstone, AWS president; Lew Gilbert; and J. F. Lincoln, guest speaker

Another view of speaker's table shows (left to right) Al Stern; J. M. Dawson, coffee speaker; F. Flocke; Bill Mayor; and J. G. Magrath, national secretary

Ed Scott (right), chairman of Cleveland Section Membership Committee, welcomes a new committee member

Not poker, but an accounting of the night's receipts, is the subject of interest here

Two generations of AWS membership are included in this father and son pose: Kenneth E. and Bruce M. MacPherson

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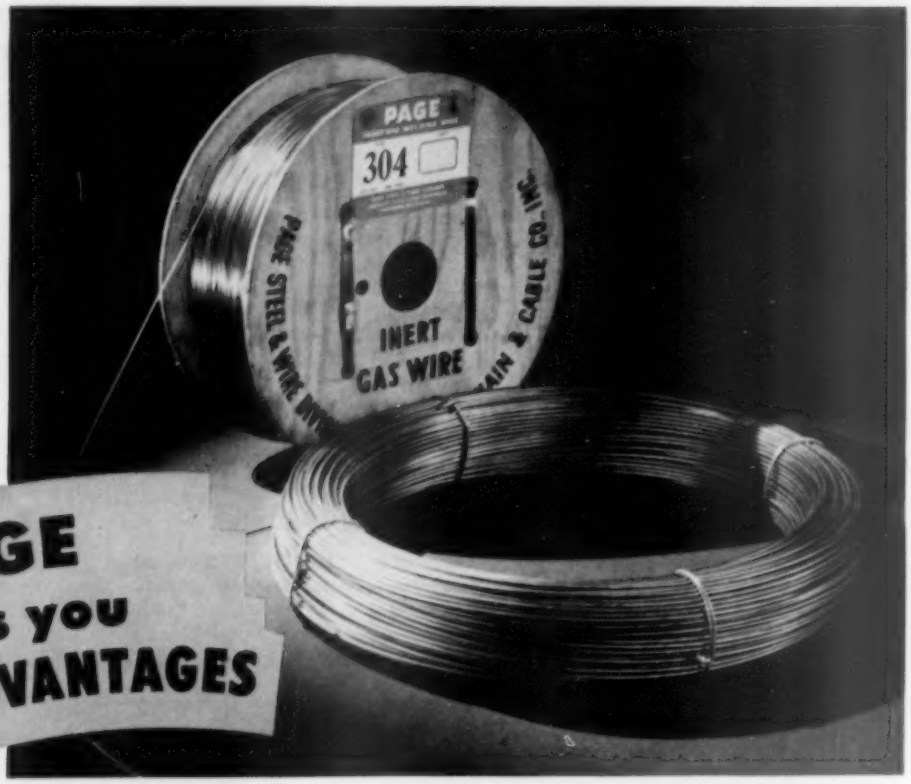

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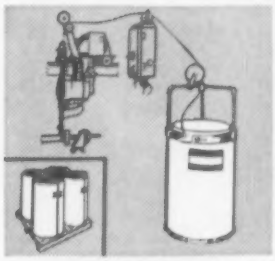

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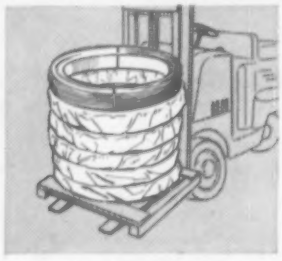

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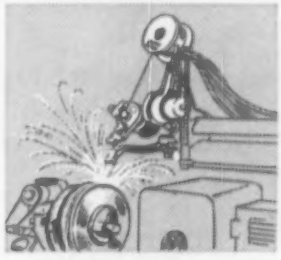

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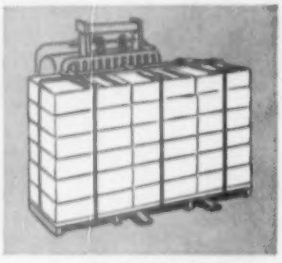

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welding machines were manufactured in 1955. He also made the following predictions for the future of the welding industry: (1) Automatic welding will replace hand welding when possible (Reason—high cost of labor); (2) larger line of alloy steel rods; (3) more use of iron-powder electrodes; (4) better design of machines for automatic welding; (5) increased use of shielded arc process; (6) education of design engineers to switch to welded construction in all places possible.

James M. Dawson, vice-president of the National City Bank, was the coffee speaker. His subject was "A Crystal Ball Look at 1956."

SPHERES AND TANKS

Denver, Colo.—An attendance of 45 members and guests were present at a dinner meeting of the *Colorado* Section held on January 10th in the Festival Room of the Oxford Hotel.

Coffee speaker, Jack Bruce, traffic engineer for the city and county of Denver discussed the traffic problems and what improvements to expect in the future.

The main speaker, L. J. Christensen, [illegible], of the Chicago Bridge & Iron Co. showed a film dealing with the fabrication of the world's largest sphere. It covered in detail the procedures used in welding the various combination parts together. In addition, the speaker showed films on the welding of spheres and tanks in the field. Mr. Christensen's presentation was excellent and well received by the members.

DESIGN FOR WELDING

Columbus, Ohio—48 members and guests of the *Columbus* Section were present on January 13th at a dinner meeting held in the Riverside Rathskeller. Speaker was John Mikulak, [illegible], of the Worthington Corp., Harrison, N. J. His subject was "Product Design for Welding."

ANNUAL STAG PARTY

Detroit, Mich.—The Annual Stag Party of the *Detroit* Section was held on December 9th at the American Legion Hall. Almost 500 members and guests gathered for a meeting which left nothing to be desired in its provisions for a good time and a chance for each member of the local welding fraternity to visit with other members. Len Nichols played Santa Claus, out of uniform, with a wonderful collection of door prizes. Favors for all in attendance and several entertainers created a real party atmosphere.

AT JANUARY 13TH MEETING OF DETROIT SECTION

J. H. Cooper, guest speaker, is shown with J. E. Rainey, section chairman

Ray Stitt, retiring District No. 6 director, congratulates Keith Sheren on his nomination for the office

AUTOMOTIVE RESISTANCE WELDING

Detroit, Mich.—The *Detroit* Section welcomed back one of its own when J. H. Cooper, of the Taylor Winfield Corp., spoke on Automotive Resistance Welding before 155 members and guests in the Engineering Society of Detroit Auditorium on January 13th. Excellent slides which accompanied the talk gave an interesting view of the big picture while Mr. Cooper supplied the details which the camera's eye could not reach. Of particular interest were the ingenious techniques used in meeting dimensional requirements on frame sections, where there was plenty of room, and in producing the required number of welds on small parts, where room was lacking.

The group enjoyed the dinner which preceded the meeting. Mr. Ray Eppert of the Burroughs Corp. gave an inspiring talk on "The Businessman and Tomorrow's Economy." His figures and reasoning, based on such undeniable realities as the number of children now with us, left no doubt that tomorrow's economy must expand. Most convincing were his arguments that there is every reason to expect this expansion to continue in an orderly fashion and for the living standards of all levels to be raised in the process.

CHRISTMAS DANCE

Appleton, Wis.—The second Annual Christmas Dinner Dance of the *Fox Valley* Section was held December 16, 1955 at the Elks Club in Appleton, Wis.

One hundred and fifty members and guests enjoyed a full evening starting with cocktails at 6:00 P.M. During the cocktail hour and dinner they were entertained by an orchestra. After dinner, door prizes were distributed, following which there was dancing until 1:00 A.M.

PLANT TOUR

Berlin, Wis.—The Berlin-Chapman Co., of Berlin, Wis., was host to the *Fox Valley* Section for a tour through their plant on November 4, 1955. About 60 members from the Fox River Valley were welcomed by Joe Jezwinski, [illegible], plant superintendent of Berlin-Chapman Co.

The group was shown through the foundry, machine shop and welding department and those present were impressed by the large part welding was playing in the manufacturing of food and dairy machinery.

After the tour, dinner was served at "Norton's" on Green Lake.

JOINING DISSIMILAR ALLOYS

East Hartford, Conn.—The welding of composite joints of ferritic and austenitic stainless steels, low-alloy steels, mild steels and high-nickel alloys were discussed by K. M. Spicer, [illegible], of the International Nickel Co., New York, at the January 17th dinner meeting of the *Hartford* Section held at the Old Colony Restaurant. Mr. Spicer's discussion also covered corrosion resistant properties, X-ray quality and other weld test results of 21 combinations of dissimilar metals.

For coffee entertainment, a submarine film entitled "Take Her Down" was shown through the courtesy of the Electric Boat Division of the General Dynamics Corp. This 12 minute film shows U. S. submarine activities through the launching of our first atomic sub, the "Nautilus."

Removal and replacement of sealed caps and sealing compound used to take National 24 hours. Now their radiographs are ready for viewing in 60 minutes.

Radiograph showing pressure seal on National Airlines' DC-7 where wing stringer enters fuselage.

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HUGE UNDERWATER

PREFABRICATING TUNNEL SECTIONS—Shown above is just one of 460, 15-ft. tunnel units being assembled in the Eddystone, Pa. shops of Baldwin-Lima-Hamilton. These units will be welded into twenty-three 300-ft. long tube sections, floated to the site, sunk and welded together to form one 6,900-ft. long underwater traffic tunnel. The welding fixture, an engineering feat in itself, was designed and built by Baldwin-Lima-Hamilton for this specific job. At the top of this photograph are shown several of the A. O. Smith DC rectifiers used in this project.

TRAFFIC TUNNEL

A. O. Smith electrodes used for over 910,000 ft. of welds. Baldwin-Lima-Hamilton tackles tough Hampton Roads tunnel contract...uses SW-10's, SW-15's, SW-44's, and SW-35's for the manual welds.

On a job this tough, Baldwin-Lima-Hamilton Corp., Philadelphia, Pa. knew there could be no margin for error. They specified A. O. Smith electrodes for the manual welding.

The work involved pre-fabricating 15-ft. double-shelled tunnel sections and welding them together to form one huge 300-ft. tube section 33 ft. in diameter. The larger sections have concrete poured between the shells, and cofferdams or bulkheads welded over the open ends. Twenty-three 300-ft. sections will be floated to the site and sunk in position to form the 6,900-ft. underwater tunnel.

Upon completion of the contract — which also includes construction of better than a mile and a half of approaches—more than 215,000 lbs. of A. O. Smith electrodes will have been used. Specifically — over 45,000 lbs. of SW-10 (E-6010) . . . 30,000 lbs. of SW-35 (E-6020)...95,000 lbs. of iron powder SW-44 (E-6024)...and 45,000 lbs. of SW-15 (E-6013).

Mr. Frank Iapalucci, director of welding on the project, specified A. O. Smith electrodes. He knows A. O. Smith electrodes give him quality and uniformity . . . welds that are right the first time . . . top production at lowest overall costs.

If your job demands top quality welds every time, talk to your A. O. Smith representative. Or — write to A. O. Smith Corporation, Welding Products Division, Milwaukee 1, Wisconsin.

At left side of photo, complete 15-ft. sections, with concrete already poured between inner and outer shell, rest in shipway. There they will be welded into large 300-ft. section as shown on the right.

Frank Iapalucci, Baldwin-Lima-Hamilton's director of welding, and Dave Buerkel, A. O. Smith welding representative, compare scale model tunnel section with blueprints to determine welding needs.

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CARBON DIOXIDE WELDING

Houston, Texas—The *Houston* Section met on January 25th in the Ben Milam Hotel, with 122 members and visitors present.

An excellent paper, entitled "C-Omatic Welding Process" was presented by R. W. Raney, AWS, General Sales Manager for A. O. Smith Corp. Mr. Raney gave a summary of the work which has been done by his company in the field of the carbon-dioxide gas-shielded metal-arc welding process and the advantages, limitations and problems encountered from the use of this welding method. Although the results obtained offer outstanding economical advantages, in many applications, there remains much more work to be done in this field which will provide further rewards according to Mr. Raney.

Colored slides showed the cross sections of welds obtained using carbon dioxide, and also showed comparative cost data charts illustrating the savings to be realized.

A bit of humor was injected into the meeting by L. Megow, who read an article on repairing a damaged space ship by welding during a flight to another planet.

CO_2 WELDING

Beaumont, Texas—Grant Annable, AWS, sales engineer for the A. O. Smith Corp. in Houston, was the speaker at the January 27th meeting of the *Sabine Division*, *Houston* Section. Mr. Annable spoke on the subject of "Carbon Dioxide Welding."

Before the meeting, a film was shown through the courtesy of the Big Three Welding Supply.

A free membership in the Society was won by one of the visitors at the meeting.

RESISTANCE WELDING FUNDAMENTALS

Moline, Ill.—A. Leslie Pfeil, AWS, president of the Universal Welder Corp., Cleveland, Ohio, was the speaker at the January 12th dinner meeting of the *Iowa-Illinois* Section held at the American Legion Club. Mr. Pfeil discussed the fundamentals of resistance welding. An excellent film on resistance welding of stainless steel was shown through the courtesy of the Allegheny Ludlum Steel Corp.

AUTOMATIC WELDING

Kansas City, Mo.—The January meeting of the *Kansas City* Section was a very well attended meeting and keen interest was expressed in the speaker, Lynn J. Christensen, AWS, of

the Chicago Bridge and Iron Co., Chicago, Ill., whose subject was "Automatic Welding Equipment and Techniques as Applied to Field Construction." Mr. Christensen presented a very interesting program which included a 16 mm sound film on the construction of the 225 ft "big sphere" which was built for the U. S. Atomic Energy Commission at West Milton, N. Y. He also accompanied his talk with very interesting slides on the subject.

At the conclusion of Mr. Christensen's talk, the meeting broke up into four separate groups to discuss the subjects of "Consumable-Electrode Gas-Shielded Arc Welding," "Jigs and Fixtures," "Resistance Welding," and "Arc Welding." Each of these groups was led by one or more men who were qualified to give help and assistance to those in need of it.

The Section plans to have similar sessions on other subjects in the months to come.

D-C RECTIFIERS

Manhasset, L. I.—Forth-five members of the *Long Island* Section met on January 12th at Patricia Murphy's Candlelight Restaurant. The meeting following the dinner was very rewarding. The speaker, G. K. Willecke, AWS, of the Miller Electric Manufacturing Co., Appleton, Wis., gave an excellent talk outlining in detail the development, function and use of direct current weld power supply with emphasis on selenium rectifiers. Comparison of d-c rectifiers, motor generators and a-c transformers, the suitability of each for the job on hand was thoroughly covered. Mr. Willecke's talk was one of the best presented to this Section; exceptionally clear, interest holding and informative to all.

LOW-ALLOY WELDMENTS

Huntington Park, Calif.—Following a short business session and dinner which was attended by 120 members and guests held at the Elks Lodge, Huntington Park, Calif., on January 5, 1956, approximately 145 members of the *Aircraft and Rocketry Panel* of the *Los Angeles* Section and delegates from the San Diego District comprising personnel from Rohr, Ryan, Convair and Solar Aircraft Companies enjoyed the pleasure of hearing Harold Armstrong, metallurgist, and Edward Harwart, AWS, welding engineer, present a paper on the subject of High-Strength Low-Alloy Fusion Weldments.

The Messrs. Armstrong and Harwart, with the use of colored slides, covered the design, fabrication and metallurgical aspects of high-strength

A sure way to meet every demand when welding high strength steels

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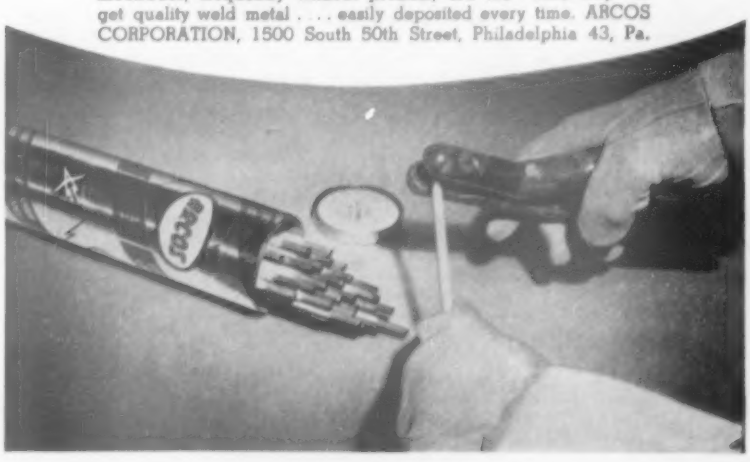


low-alloy steel weldments used in the fabrication of component parts for the B-52 jet bomber. Both Mr. Armstrong and Mr. Harwart made an excellent delivery on the subjects covered.

Mr. Armstrong is a graduate metallurgical engineer of the Colorado School of Mines and has been affiliated with Rohr since 1953.

Mr. Harwart is a graduate of the Ohio State University, with a Bachelor Degree as a welding engineer, and has been associated with the Rohr Aircraft Corp., since June 1955 as a Welding Engineer.

Both speakers were given desk pens at the conclusion of their paper in appreciation of their contribution.

DISTORTION CONTROL

Madison, Wis.—The *Madison* Section met on January 26th for dinner and meeting at the Eagles Club House. Coffee speaker was Prof. Archie H. Easton of the University of Wisconsin. His subject "Safe Practices in Winter Driving" proved to be a most appropriate presentation at this time of the year. His talk was accompanied by slides and a short movie which dealt with precautionary steps under icy conditions. From exhaustive tests that Professor Easton has personally directed he has come up with concrete results in regards to tires, transmissions, brakes and the new power features that are popular now in steering and braking.

The technical program was handled very well by LaMotte Grover, AWS, welding engineer for the Air Reduction Sales Co. in New York. His subject, "Prevention and Control of Distortion in Welding," attracted many interested people from the larger steel fabricating firms in this area. The question and answer period that followed lasted forty minutes, which proved the keen interest of the members and guests.

Mr. Grover gave some valuable tips in the control of distortion and cracking. Throughout his address, he also stressed the application of common sense. Time did not permit Mr. Grover to cover even a minor portion of his knowledge on distortion control and one can readily see where his past affiliations with shipbuilding and bridge building proved to be a big asset to these people.

PLANT TOUR

Sharon, Pa.—The September meeting of the *Mahoning Valley* Section, held on September 15th, was in the nature of a plant visit to the Sharon Steel Corp. in Sharon, Pa. The tour under the direction of J. E. Sowers, consisted of a trip through the Finishing Departments, Division "A" of the Roemer Works. The operations which were seen on this tour were heating and rolling semi-finished slabs and billets into bars and steel strip; also, modern annealing and cleaning processes. The tour was very interesting and educational.

A short technical meeting followed the tour.

HEAVY WALL PIPE

Warren, Ohio—The October dinner meeting of the *Mahoning Valley* Section was held on October 20, 1955 in the El Rio Club at Warren.

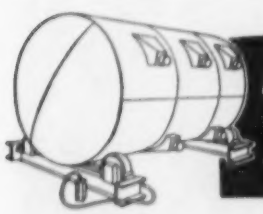
There was a below average attendance at this meeting due to the fact that the Metals Show was being held at the same time.

N. C. Jessen, AWS, of the Babcock & Wilcox Co., Barberton, Ohio, presented a very interesting program on "Manufacture of Heavy Wall Pipe." Mr. Jessen's illustrated talk gave the progress in the production of heavy wall pipe, starting with the actual melting of the metal to the final inspection. The process which is used is known as the pierce and drawn method.

RESISTANCE WELDING MACHINERY

Warren, Ohio—The November dinner meeting of the *Mahoning Valley* Section was held on November 17th in the El Rio Club at Warren, Ohio. An above average crowd was in attendance.

F. R. Woodward, AWS, of the Taylor-Winfield Corp., Warren, Ohio, presented his portion of the program on



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cost no more than ordinary rolls!

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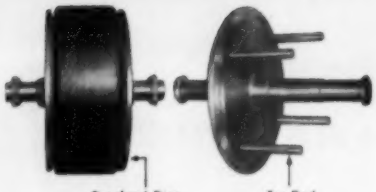

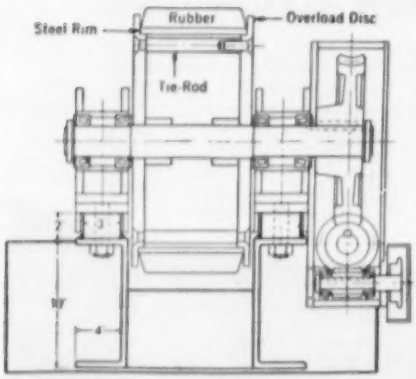

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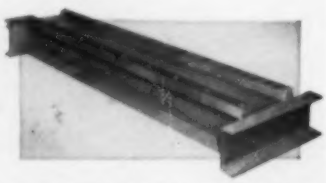

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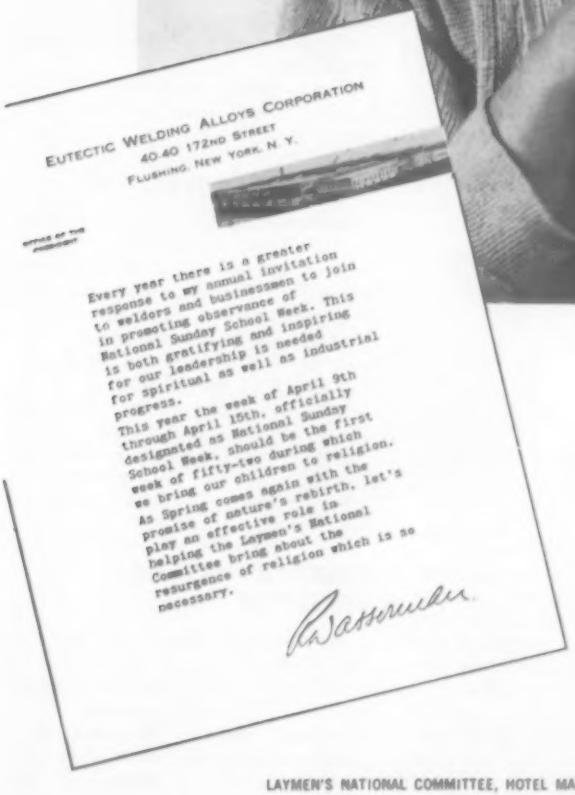

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OFFICE OF THE PRESIDENT

Every year there is a greater response to my annual invitation to welders and businessmen to join in promoting observance of National Sunday School Week. This is both gratifying and inspiring for our leadership is needed for spiritual as well as industrial progress.

This year the week of April 9th through April 15th, officially designated as National Sunday School Week, should be the first week of fifty-two during which we bring our children to religion. As Spring comes again with the promise of nature's rebirth, let's play an effective role in helping the Laymen's National Committee bring about the resurgence of religion which is so necessary.

R. Wasserman

"SUNDAY SCHOOL... THE GUIDE TO A BETTER WORLD."

NATIONAL
SUNDAY
SCHOOL
WEEK
APRIL 9-15

LAYMEN'S NATIONAL COMMITTEE, HOTEL MANGER VANDERBILT, N. Y. 16, N. Y.

"Developments in Resistance Welding Machinery." Mr. Woodward elaborated on the current design and application of resistance welding machinery and showed slides and a short movie with his talk.

ARC CUTTING

Warren, Ohio—The January dinner meeting of the *Mahoning Valley* Section was held on January 19th in the El Rio Club at Warren. Thirty-five members and guests disregarded one of the area's most severe snow and ice storms to hear Edward H. Roper, AWS, of the Air Reduction Sales Co., New York.

Mr. Roper discussed the use of the inert-gas-shielded consumable-electrode arc welding process for cutting purposes.

By using higher than normal currents and speeds, this process may be used to make cuts in aluminum stainless steel, monel, inconel and copper plate. Using only standard equipment, quality cuts may be made in thicknesses up to one-half inch and severing cuts are achieved in much greater thicknesses.

Mr. Roper illustrated the process with slides and movies and displayed a number of actual samples of this interesting process, which brings the ease of the oxyacetylene cutting of mild steel to metals not normally readily cut by the torch.

AUTOMOTIVE WELDING

Baltimore, Md.—The January meeting of the *Maryland* Section was held Friday, January 20th, at the Engineers Club in Baltimore.

The technical speaker for the evening was John F. Randall, AWS, of the Welding Development and Plastic Prototype Section, Stamping Process Department, Ford Motor Co. He used as his subject "Automotive Welding," accompanied by slides. His talk was well delivered and quite interesting conveying a wide knowledge of the industry. Mr. Randall has been with the Ford Motor Co. as supervisor of welding development since January 1946.

The after-dinner talk was presented by Thomas P. MacCarthy, Master in Chancery for the Domestic Relations Court in Baltimore. He used as his subject "Problems of Delinquent Youths." Quite interesting.

There was a good attendance at the dinner and technical meeting.

SHIPYARD WELDING

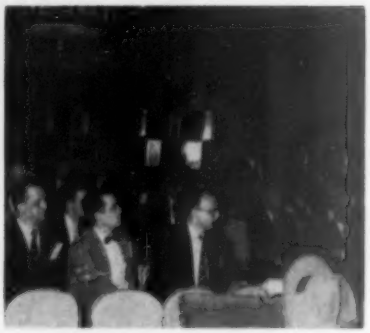
Newark, N. J.—Eighty-six members and guests attended the January 17th meeting of the *New Jersey* Section held at the Essex House Hotel in Newark.

The speaker for the evening, R. D. Bradway, AWS, welding engineer for the New York Shipbuilding Corp. spoke on "Welding Fosters Diversifications in Shipyards." After a brief explanation of why shipyards are a "natural" for other types of work other than shipbuilding, Mr. Bradway described with the help of slides the precambering of long and heavy bridge beams by machine torch shrinking. Then followed his principle subject, the fabrication and assembly of 21,000 ton twin tube sections of the vehicle tunnel around Baltimore, Md. These huge sections, 300 feet long, bulkheaded on each end and lined with twenty inches of concrete were built up from subassemblies and launched as a ship and towed to the building site.

The audience interest in Mr. Bradway's talk was evidenced by the prolonged question and answer period. This was followed by the usual snack and get-together.

BRADWAY SPEAKS BEFORE NEW JERSEY SECTION

R. D. Bradway (left) being presented with souvenir by H. L. Hoffman. Mr. Bradway spoke on the role played by welding in shipyards



The question and answer period which followed Mr. Bradway's talk was a long and spirited one. This is a typical scene

RECTIFIER POWER SUPPLIES

New York, N. Y.—"Rectifier Power Supplies for Welding" was the subject of a paper presented to the *New York* Section on January 10, 1956. G. H. Willecke, AWS, Physicist with the Miller Electric Mfg. Co., Inc., Appleton, Wis., was the speaker.

Mr. Willecke gave a thorough discussion of various apparatus used in the welding technique. With the background of motor generator sets which were first used in welding, Mr. Willecke then went on to explain the use of rectifiers and their application in the welding industry. Such rectifiers as the vacuum tube, the thermionic gas tube, the electrolyte, and the crystal detector were explained. The dry disk or metallic rectifier in which selenium is used was explained in great detail, in operation as well as in construction. The presentation of the subject was excellent and was conveyed to the audience in such a manner that every one present could easily understand the details and the operation of the rectifier.

Directly before Mr. Willecke's presentation, a film was shown entitled "Nickel." This is a 16-mm sound film showing the mining operations by the Nickel Company in Canada. The film was very interesting and showed all the various methods in mining as well as handling of the ore.

The meeting was held at the Schwartz Restaurant, 54 Broad St., New York City, N. Y.

RESISTANCE WELDING

Marion, Ohio—The dinner meeting of the *North Central Ohio* Section held on the second of December at the Hotel Harding, was extraordinarily successful. Approximately 60 members and guests attended. Cocktails were enjoyed prior to the dinner.

Karl W. Matthes, AWS, chief development engineer for Precision Welder & Flexopress Corp. spoke on resistance welding fundamentals and applications. He also presented a movie entitled "This is Resistance Welding."

FABRICATION AND ERECTION

Minneapolis, Minn.—H. Jackson, AWS, of the Thompson Pipe and Steel Co., Denver, Colo., was the speaker at the January 9th meeting of the *Northwest* Section. Members thoroughly enjoyed his informative talk featuring slides of fabrication and

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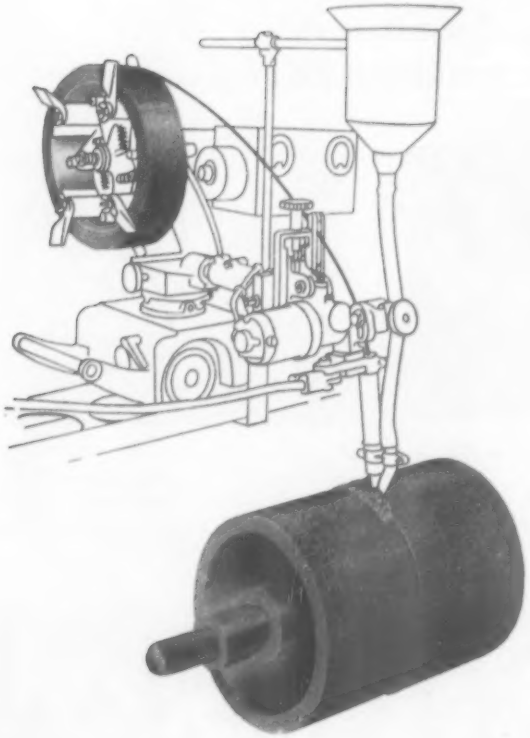

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erection techniques used by the speaker's company.

RESISTANCE WELDING

Bradford, Pa.—The October meeting of the *Olean-Bradford* Section was held at the Valley Hunt Club, Lewis Run, Pa., on October 24th.

The well attended meeting was addressed by Jack B. Keyte, [illegible], welding engineer of the Dresser Manufacturing Division, Bradford, Pa., who gave an excellent talk on Resistance Welding. Particular emphasis was given by Mr. Keyte to the flash welding process. Basic principles were clearly explained and differences in production flash welding equipment were pointed out together with their respective advantages and disadvantages. Flash welding techniques for mild and low-alloy steels; stainless steels and heat resistant alloys as used in jet engine construction for the aircraft industry were discussed. The talk was well illustrated by slides and supported by a film entitled "Resistance Welding of Stainless Steels," shown through the courtesy of the Allegheny Ludlum Steel Corp. of Pittsburgh, Pa.

Much discussion and many questions were prompted by the talk, ample testimony that members had found the evening interesting and informative.

QUIZ PROGRAM

Bradford, Pa.—A quiz program—with a new twist—formed the basis of the November meeting of the *Olean-Bradford* Section held on November 21st. All members present were invited to pose questions, particularly those concerning current day-to-day welding problems, for discussion and possible solution by the group as a whole. Moderator for the evening's activities was Michael N. Robinson. The evening was successful in that everyone was encouraged to participate and several interesting discussions ensued ranging over such topics as contact iron-powder electrodes, cutting techniques for aluminum alloys, methods of joining aluminum, distortion and the welding of stainless steel alloys.

The importance of using the Section's accumulated "know-how" to help overcome individual problems involving welding and allied processes was stressed and it was urged that members should take advantage of such "know-how" not only at Section meetings of the type held during the evening but whenever occasion might demand it.

MAINTENANCE WELDING

Peoria, Ill.—The January 18th dinner meeting of the *Peoria* Section was held at the Mecca Supper Club in Peoria.

Donald Caldwell, [illegible], a supervisor in charge of maintenance welding at Caterpillar Tractor Co. was the speaker.

Mr. Caldwell gave a good talk on maintenance welding, and showed slides describing various maintenance work on different materials. In conjunction with maintenance welding, Mr. Caldwell explained how welding circuit maintenance was being accomplished with a copper thermit process and neoprene vulcanizing.

ZIRCONIUM VESSELS

Philadelphia, Pa.—The January 16th meeting of the *Philadelphia* Section was held at the Engineers Club.

The meeting was preceded by dinner at which over sixty were present. It being Ben Franklin Week, commemorating the 250th anniversary of his birth, the after dinner speaker, Melvin K. Whiteleather, noted correspondent and commentator of the Philadelphia Bulletin, gave a very interesting and humorous talk on the other, or private life of Ben Franklin.

The speaker of the evening, Edward C. Miller, [illegible], has been engaged since the end of World War II, in reactor development metallurgy with the Oak Ridge National Laboratory. Mr. Miller discussed "Fabrication of a Zirconium Vessel for an Atomic Power Reactor." He pointed out the qualifications of various metals which would stand up under the heat involved and their ability to afford the free transfer of neutrons. Zircalloy 2 was decided upon for this 32-in. diam core vessel. The welding was done with the inert-gas tungsten-arc process, using helium as the shielding and back-up gas. It was pointed out that zirconium takes up all the impurities in gases; therefore, the gases used must be extremely pure. This discussion was well illustrated with slides.

PHILADELPHIA SECTION ADDRESSED BY MILLER AND WHITELEATHER

Shown in this group are A. M. Garcia, section vice-chairman; E. C. Miller, technical speaker; E. E. Goehringer, section chairman, and M. K. Whiteleather, after-dinner speaker

Mr. Miller is pictured above while addressing the members present. His talk dealt with the timely subject of the fabrication of a zirconium vessel for an atomic power reactor

Part of the large and attentive crowd gathered at the Engineers Club on January 16, 1956

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Napolitan Sheet Aluminum Welding Flux. Formula 40 is unsurpassed for welding aluminum and its alloys in either sheet or cast form. *Formula 42* generally is satisfactory to use for a variety of work where reduction of welding costs is a factor. It is less expensive than formula 40.

Airco Aluminum Brazing Fluxes. Formula 44 is designed, primarily, for furnace brazing of brazable alloys. *Formula 60* is primarily for torch brazing of aluminum.

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CO_2 WELDING

Pittsburgh, Pa.—The regular monthly dinner meeting of the *Pittsburgh* Section was held on January 18th in the Hunt Room of the Hotel Webster Hall and the Mellon Institute, Industrial Research Building. Speaker at the technical meeting was John P. Koss, AWS, Supervisor, Research Laboratory, A. O. Smith Corp., Milwaukee, Wis. His subject was "Carbon-Dioxide-Shielded Metal-Arc Welding Process." Mr. Koss summarized the work done by his company with this method, including the equipment required.

Through the courtesy of the Allegheny Ludlum Steel Corp., of Pittsburgh, a movie entitled "Big Saul" was shown before the meeting.

IRON-POWDER ELECTRODES

Portland, Ore.—The monthly meeting of the *Portland* Section was held on January 10, 1956 in the Golden Room of the Old Heathman Hotel.

A social period starting at 6:30 P.M. gave the members an ample opportunity to get acquainted with guests and new members.

The speaker of the evening, Harold F. Reid, AWS, Technical Service Division, McKay Co., was introduced by Vice-Chairman, Earl Babitt. His timely topic, "Iron-Powder Electrodes—Yes or No" was adequately covered by tracing the history and development of these electrodes, reviewing their advantages, and noting cautions which should be used when welding with them. He stressed the advantages of more effective use of current, increased speed of deposition, possible reduction of operator fatigue, less training time required when electrode is used, decreased penetration which allows some critical metals to be welded without preheating, and the greater footage of weld obtainable per electrode used. Mr. Reid cautioned the operators to look for some disadvantages in using iron-powdered electrodes such as: surface porosity if excess amperage is used, poor bead contour or V notch effect when proper speed or amperage control is not maintained, and poor cleaning which may result if moisture is picked up by improper storage of materials. A lively discussion period followed.

DINNER DANCE

Richmond, Va.—The December meeting of the *Richmond* Section was held in the form of a dinner dance at Forest View Supper Club on Friday, December 16, 1955.

Approximately forty-five members, wives and guests were present for an excellent steak dinner, followed by dancing to the music of a small orchestra. Door prizes for the ladies took the form of numerous pairs of nylon stockings.

This was the first Christmas party that the Richmond Section has held, and the enthusiasm with which it was received gives every indication that the affair will be repeated in the future.

INERT-GAS WELDING

Richmond, Va.—The January 1956 meeting of the *Richmond* Section was held in the Monticello Room of the Holloway House on Thursday the nineteenth.

The thirty-two members attending gathered at 6:30 P.M. for a brief social period which preceded the dinner and meeting.

Speaker at the meeting was W. O. Couch, AWS, of the Air Reduction Sales Co. Mr. Couch spoke on "Inert-Gas Tungsten-Arc Welding." In a very interesting talk, he traced the origin and history of the process and its present and future possibilities. He outlined the advantages which this process has in the welding of the various semi-precious metals which are being fabricated today.

After his talk, Mr. Couch presented an Airco movie entitled "Nothing but the Best," which illustrated his talk.

ALUMINUM WELDING

Rochester, N. Y.—The *Rochester* Section met at a dinner meeting on January 16, 1956. Seventy members and guests enjoyed two outstanding talks on aluminum joining.

The first speaker was Paul Dickerson, AWS, Alcoa of Pittsburgh, who gave an illustrated talk entitled "Recent Advances in Aluminum Welding." It included descriptions of consumable-electrode and tungsten-arc welding and cutting.

The second speaker was W. S. Hamilton, AWS, Alcoa of Pittsburgh, whose subject was "Brazing Aluminum Alloys." Following his description of the materials, processes and techniques used in brazing aluminum, the movie "New Horizons in Aluminum Brazing" was shown.

WELDED FABRICATION

Saginaw, Mich.—J. R. Stitt, AWS, research and welding engineer, R. C. Mahon Co., Detroit, was the speaker at the January 12th dinner meeting of the *Saginaw Valley*

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BRUSH TALKS ON BOILING WATER REACTOR BEFORE SAN FRANCISCO SECTION

Boiling water reactor was subject of talk presented by Harvey Brush before San Francisco Section on January 23rd.

Speaker's table is shown at left, while view of large crowd in attendance is given at right

Section held at the High Life Inn with an attendance of 100.

Mr. Stitt's interesting discussion dealt with "Welded Fabrication and Flame Straightening."

BOILING WATER REACTOR

Oakland, Cal.—Ninety-five members and guests attended the dinner meeting of the *San Francisco* Section held in Plands Restaurant, Oakland on January 23rd. They heard Harvey Brush of the Bechtel Corp., San Francisco, describe the Boiling Water Reactor being built at Argonne National Laboratory for the AEC. Mr. Brush, now at work on the 180,000 KW reactor for Commonwealth Edison and the other members of the Nuclear Power Group, has been a member of the Bechtel Corp.-Pacific Gas & Electric Co. Nuclear Power Study Team since its formation. He also spent a year at Argonne National Laboratories on the Experimental Boiling Water Reactor Project.

After the Geneva Conference on peace-time uses of nuclear energy, it became possible to discuss many phases of the work which had been done toward developing the AEC's five-year plan for atomic power reactors. Of the five reactors approved for test by the AEC—pressurized water, boiling water, homogeneous, sodium graphite and fast breeder—Mr. Brush described the experimental boiling water reactor being erected at the Argonne National Laboratory, since he had participated in its design.

The guest speaker explained in detail the functions of the various parts of the reactor and outlined the factors to be taken into account for proper design. The first thing to consider, Mr. Brush said, when locating a reactor in a populated section, is the protection of the area from the accidental release of radioactive material. This reactor itself and much of the auxiliary and ancillary equipment will therefore be housed in a steel container constructed in accordance with the rules of the Boiler Code plus safety refinements required by the AEC. The volume of the container is necessarily large since it is designed to contain the steam which would be generated should all the water in the system be vaporized. An added expense was the 12-in. concrete lining provided in all machinery compartments to prevent puncture of the container should the equipment ever explode.

WELDING ALUMINUM ALLOYS

Syracuse, N. Y.—The January dinner meeting of the *Syracuse* Section was held in the Hiawatha Room of the Hotel Onondaga on January 11th.

The coffee speaker, Lt. Col. Hale, stationed with the U.S.M.C. at Hancock Field, explained the technical and educational advantages offered to young men entering the armed services.

William M. Rogerson, director of welding research for the Aluminum Company of America, covered all aspects of welding and brazing aluminum alloys in a very interesting and informative manner.

He noted especially that small welding shops could adapt available equipment to do specific jobs.

Some examples of this are: regular arc welding equipment can do a satisfactory welding job using the latest type coated electrodes provided the electrodes are overdried to reduce spatter. Inert-gas-shielded tungsten-arc torches can be adapted for cutting aluminum by using 65% hydrogen and 35% argon under a special patented process.

Mr. Rogerson said that welding appears to be the best method of joining aluminum and that high production rates are possible if careful thought is given to the method employed.

RESISTANCE WELDING CONTROLS

Toledo, Ohio—Len Broniak, [illegible], of the Weltronic Corp., Detroit, was the speaker at the January 17th dinner meeting of the *Toledo* Section held at the Maumee River Yacht Club. Mr. Broniak gave an excellent discussion on the elements that go into the timing device that is so important to good resistance welding. He accompanied his talk with slides and blackboard illustrations.

AUTOMATION

Springfield, Mass.—The first of two meetings of the *Western Massachusetts* Section on the subject of "Automation" was held on Tuesday, January 10th at Blake's Restaurant.

A panel consisting of Sidney Low (Moderator) of the Chapman Valve Manufacturing Co., John Mortimer of the Whitlock Manufacturing Co., and Frank Wallace of Pratt and Whitney Aircraft, presented many points for both sides on this timely subject. These points incuded: what is automation; what are its advantages and disadvantages; will automation take the place of human welders; when should one consider automation? Also what engineering studies and general cost data must be

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on hand to determine whether automation should be applied to a given job?

CAR BUILDING INDUSTRY

Worcester, Mass.—The January meeting of the *Worcester* Section was held as scheduled on Monday evening, January 9th. Even though this was one of the worst evenings for weather, 44 members showed up for the dinner and 54 for the meeting. They were rewarded for their fortitude. Speaker was J. L. Forand, [illegible], welding engineer at the Pullman Standard Car Manufacturing Co. plant in Worcester.

Mr. Forand in his remarks covered the car building industry in Worcester from its inception by Osgood Bradley in 1832, through its many phases and company ownerships up to the present day.

At the beginning of the railroad industry, Mr. Bradley took what amounted to a replica of the Stage Coach in use then and mounted it on flanged wheels. That became the railway coach of the very early period of railroading. Through the early period and until about 1910 this factory worked almost entirely with wood. In 1910 the Osgood Bradley Car Co. was taken over by the Standard Steel Car Co. and from that time on its product became steel car instead of wood. The transition from wood to steel saw a great deal of wood car design duplicated in steel. This went on for nearly 20 years before an out-and-out steel car design was available. During this period attachments in general were made by driving hot rivets.

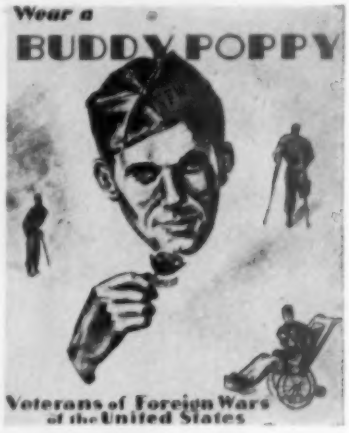
This era lasted only a short time, and in the late nineteen thirties welding became a factor so that design had to be changed again. With the improvements that welding naturally made the engineers were able to reduce the weight by about 30% without sacrifice of strength or affecting the life of the car.

The Pullman Worcester plant, employs welding almost exclusively.

Mr. Forand illustrated his remarks by showing a large number of slides, each showing some machine, process, or component part of a car, either in assembly or subassembly. The pictures were very instructive and invited many questions from those present, many of whom had not seen this much equipment. They were interested in voltages, welding speeds, fit ups, etc.

RESISTANCE WELDING APPLICATION

York, Pa.—J. H. Cooper, [illegible], chief sales engineer of the Taylor-Winfield Corp. in Warren, Ohio, gave a well documented talk on resistance welding application at the January 10th meeting of the *York Central Pennsylvania* Section. Numerous slides showed new applications of projection, butt, and flash welding used in automotive, heavy appliance, and aircraft industries.



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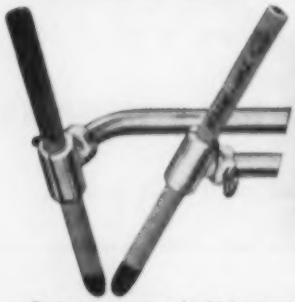

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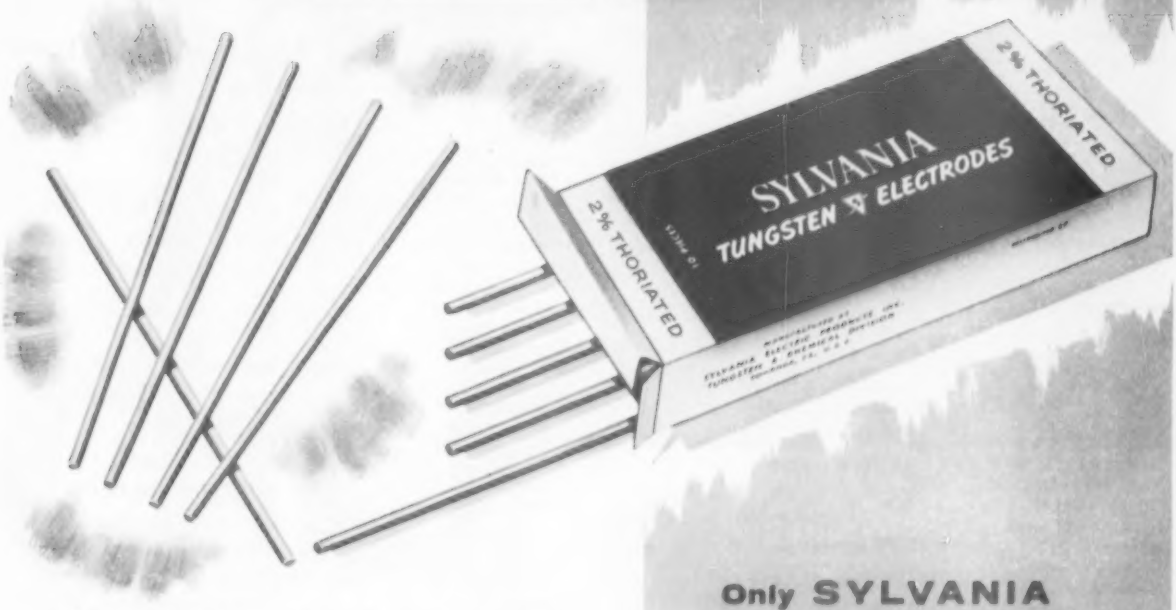

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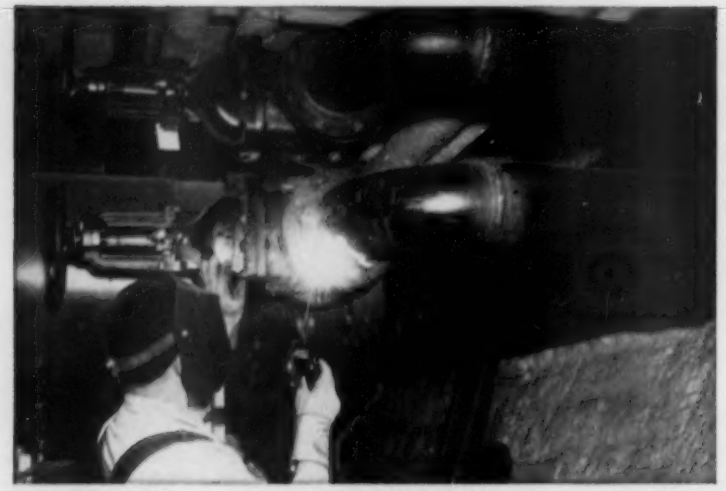

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ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington 25, D. C.

2,727,972—Control of Arc Melting, Welding, and Heating—Clifton S. Williams and Edwin W. Johnson, Pittsburgh, Pa., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This patent is particularly directed to the arc melting of material of the molybdenum type from a consumable rod. The method comprises the steps of imposing both an alternating potential and a variable direct current potential between the rod and the material to produce an arc for melting the rod and the material under the composite potential impressed thereon. Then the magnitude of the direct current is varied as the melting progresses to maintain the rate of melting of the rod and the heating of the material in the ranges within which satisfactory operation is produced.

2,728,031—Impulse Welding Control—Edward C. Hartwig, Walnut Creek, Calif., and Hubert W. Van Ness, East Aurora, N. Y., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This patent is on a special impulse welding control system wherein first and second supply conductors are provided and first and second load conductors are present. A pair of ignitrons, firing valves, firing capacitors and other means are used to connect the ignitrons in a desired control circuit.

2,728,046—Combination Single-Phase Line Frequency Welder and Impulse Welder—David Sciaky, Chicago, Ill., assignor to Welding Research, Inc., Chicago, Ill., a corporation of Illinois

This patent is on a combination welding system including a transformer having inductive relation with a secondary load circuit. The transformer is connected to a source of alternating current through a pair of asymmetrically conducting electric discharge valves so that each valve will pass one half cycle of the alternating current to the transformer. Hence, either positive or negative pulses of uni-directional current are induced in the secondary load circuit connected to the transformer and in effect an alternating current is induced in the secondary load circuit having the same frequency as the source current.

2,728,838—Welding Electrode Holder—Chalma V. Barnes, Hammond, Ind.

In this patented electrode holder, a bar is slideably positioned on a handle member. The slideable bar includes an end portion providing a jaw cooperable with one end of the handle member for receiving and clamping an electrode there between. Means are provided for actuating the slideable bar.

2,729,180—Spiral Pipe Machine—Jonathan Roy Freeze, Middletown, Ohio, assignor to Armco Steel Corp., Middletown, Ohio, a corporation of Ohio.

This machine is adapted to make spiral welded pipe from metal stock. The machine has rolls for feeding the stock forwardly and bending means to form the stock into a helix. Both of these means have their axes in horizontal planes and the bending means are stationary and disposed at an oblique angle to the feeding means. The feeding means are movable so that their angular relationship to the bending means can be varied

2,729,558—Silver Brazing Alloys—Ross Bayes, Basking Ridge, and Henry B. Aull, Livingston, N. J., assignors to the American Platinum Works, Newark, N. J., a corporation of New Jersey.

A special brazing alloy especially suited for uniting base metals to produce a joint capable of withstanding high stresses and temperatures is covered by the present patent. The alloy contains specific amounts of copper, zinc, manganese and silver.

2,729,578—Welding Apparatus and Method—Oscar Hedlund and Joseph Arthur Edwards, Jr., Battle Creek, Mich., assignors to Eaton Manufacturing Co., Cleveland, Ohio, a corporation of Ohio.

The patented method relates to applying weld metal to a desired area of an engine valve or similar article. The article is positioned adjacent a stationary welding head for simultaneous rotary and traversing movements. The welding head is used to produce a weld formation on the article which is given movement to deposit the weld formation spirally over the desired area of the engine valve along convolutions lying at different radial distances from an initial weld point. The rate of speed of rotation and traversing movement is varied so that the adjacent convolutions of the weld formation are disposed in juxtaposed relation and aggregate on and cover the entire desired area.

2,729,580—Method of Improving the Uniformity of Corrodibility of Welded Nickel Anodes—Walter L. Pinner, Detroit, and Orville D. Hoxie, Farmington, Mich., assignors to Houdaille-Hershey Corp., Detroit, Mich., a corporation of Michigan.

This patent is on the making of a composite welded anode comprising welding metal sheets together to form an anode wherein both the weld metal and the metal sheets are made from electrolytic nickel. The welded anode is then subjected to a heat treatment within the range of 1400 to 2100° F to effect a substantially equalized grain growth of the nickel in the anode in and around the weld and to decrease corrodibility of the weld.

2,729,881—Composite Metal Article of Chrome Steel and Platinum Components.— Max Joseph Stumbock, South Orange, N. J., assignor to Baker & Co., Inc., Newark, N. J., a corporation of New Jersey.

Stumbock's composite metal article is made from two or more metal parts having two abutting surfaces. One of these parts is of chrome steel on its abutting surface and the other of the abutting parts being of a platinum alloy. A brazing alloy is provided between the surfaces and bonded thereto, which alloy consists of 60% palladium and 40% copper and has a melting point of about 1200° C.

2,730,465—Electrical Arc Welding—Paul Christiaan van der Willigen, Eindhoven, Netherlands, assignor to Hartford National Bank and Trust Co., Hartford, Conn., as trustee.

Willigen's patent is on a welding electrode comprising a metal core having a diameter of 10 mm, and a slag-forming conductive coating for the electrode. The coating is adapted to pass a current capable of initiating a welding arc on contact of the coating with the workpiece. The coating includes calcium fluoride, calcium carbonate, ferrous alloys, pulverulent iron, water glass and aluminum silicate.

2,730,599—Pressure Welding by Induction Heating—Bela Ronay, Harundale, Glen Burnie, Md.

Ronay's patent is on an induction heating apparatus suitable for use in pressure welding operations. A primary coil is provided as is a secondary coil positioned in inductive relationship to the primary coil. The secondary coil is in the form of a tube having a single axial slit in the wall thereof and a transversely projecting flange of narrow axial width. This flange overlies the workpiece to be heated and is adapted to develop in the workpiece a heated band of a width approximately equal to that of the flange.

"I like Airco 78E Electrodes because slag is so easy to remove"

Easy slag removal is just one of the many advantages of Airco 78E electrodes. This deep penetrating, all position electrode produces high quality weld metal which sets up rapidly. It is free from porosity, even when welding in the vertical down position. Especially recommended for welding mild steel where high ductility and tensile strength are essential.

This is but one of many electrodes in Airco's complete line that also includes stainless steel, hard-facing, cast iron, general and special purpose electrodes. Send for the free Airco Electrode Guide which will help you select the right electrode for your specific job. Request catalog 1318-WJ.

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2,730,600—Rotating Electrode Structure—Simon Fisher and Thaddeus S. Kurlinski, Bay City, Mich., assignors to National Electric Welding Machines Co., Bay City, Mich., a corporation of Michigan.

The present patent particularly relates to a rotating resistance welding electrode structure that has a coolant circulated through the shaft. By the teachings of the patent, a shaft is positioned in a housing by frictionless bearings, while a smooth contact area is provided on the shaft intermediate the bearings. Contactor blocks bear against such smooth contact area and wedge and control means are provided for urging the contactor blocks against the smooth contact area.

2,730,601—Resistance Welding Machine for Sheet—Eo Reed, Middletown, Ohio, assignor to Armco Steel Corp., Middletown, Ohio, a corporation of Ohio.

Reed's patent is on a method of welding metal sheets in end to end relation to form a metal strip. The method includes bringing the leading edge of a sheet into abutment with a trailing edge of a preceding sheet and deforming such edges out of the plane of the sheets. The sheets then have a resistance welding current passed through such abutting edges and such edges are forced back into the plane of the sheets at the same time. The welding current circuit is moved along the abutting edges for the welding action.

2,730,646—Electric Arc-Welding Apparatus—Peter Thomas Houldcroft and John Guy Purchas, London, England, assignors to British Welding Research Association, London, England, a corporation of Great Britain.

This patent is on an automatic feed for a consumable arc-welding electrode. The patented apparatus includes feed members, a differential gear train comprising two in-put members and an out-put member, and a driving connection is provided between the out-put member and at least one of the feed members. Two motors are connected to drive the in-put members in opposite directions and means are provided and controlled by the voltage across the arc for varying the speed of one of the motors directly with changes in value of such voltage. Other means are controlled by the voltage for varying the speed of the second motor inversely with changes of the value of such control voltage.

2,730,995—Pneumatic Actuation of Machine Elements, Particularly Resistance Welding Electrodes—Melvin M. Seeloff and Hans Henning Hansen, Warren, Ohio, assignors to the Taylor-Winfield Corp., Warren, Ohio, a corporation of Ohio.

This patent is on a double-acting pneumatic motor specially adapted for positioning resistance welding electrodes.

2,731,373—Electrode Flux Covering for Copper and Copper-Base Alloy Core Materials—Rene David Wasserman, Stamford, Conn., and Joseph Quaas, Island Park, N. Y., assignors to Eutectic Welding Alloys Corporation, New York, N. Y., a corporation of New York.

This patent is on a composition suitable for application to a metallic electrode core for use in electric arc welding. The mixture comprises substantially equal parts of calcium carbonate, calcium fluoride, lepidolite and titanium dioxide to form approximately 80% of the composition therefrom. The remainder of the composition consists of deoxidizers and slag-forming constituents of specified materials.

2,731,534—Fluid Pressure Actuator for Machine Components—Hans H. Hansen and Melvin M. Seeloff, Warren, Ohio, assignors to the Taylor-Winfield Corp., Warren, Ohio, a corporation of Ohio.

This patent is on a movable electrode assembly for a low-inertia resistance welding machine having quick weld follow-up characteristics. The assembly includes an elongated housing having a reciprocable slide member within such opening and carrying a movable electrode. A lightweight piston is provided in a cylinder and connects to the slide member. A flexible diaphragm is provided in the piston and its control cylinder so that fluid pressure entering a control cylinder will move the piston and slide member in a direction toward the work to be welded with a minimum of resistance. Thus the end of the movable electrode will follow up the receding work surface as such surface softens under the heat generated by the provided welding current.

2,731,535—Electrode for Attaching Weld Nuts—Gregory F. Grey, Berea, Ohio, assignor to The Ohio Nut & Bolt Company, Berea, Ohio, a corporation of Ohio.

Grey's patent relates to a welding apparatus for indexing and welding a weld nut or the like on a support member. The electrode has a bore extending therein from an end contact face provided thereon and a pilot member is slideably supported for longitudinal movement in such bore for special aligning action.

2,731,536—Welding Wire Positioning—Eugene Laur, Lewiston, N. Y., assignor to Union Carbide and Carbon Corp., a corporation of New York.

This patent relates to a method of inert-gas-shielded-arc welding in which the arc forms a weld puddle. This puddle is shielded by a stream containing inert gas and a wire is fed by wire feeder means inside a conduit and through a guide into the weld puddle. A feature of the method comprises positioning the end of the wire longitudinally with respect to the guide by causing relative movement of the conduit and guide longitudinally of the wire with respect to the wire feeder means.

Current Welding Literature

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THE WIDE-RANGE, ALL-PURPOSE WELDING TORCH

This is the torch *par excellence* for all types of work, from 28 gauge sheets to 1" slabs or more. Has easy-adjustment non-seizing valve mechanism for precise control of gas pressure and flow. Mixer blends gas perfectly, delivers to tip without restriction. Both swaged and drilled tips are available to provide required flame characteristics.

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THE LIGHT AND MEDIUM DUTY WELDING TORCH

For automotive welding, pipe welding, sheet metal fabrication, steam-fitting, etc. Aluminum handle, lightweight but rugged. Valve wheels placed conveniently at front end, under the thumb. Mixer delivers perfectly mixed gases. Mixer has buna seating rings for leakproof hand-tightening.

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Ideal for welding aluminum, alloys, aircraft tubing, steel from 28 gauge to ⅛" thick. Lightweight, easy to handle, compact for use in tight quarters.

Valve wheels placed conveniently at front end, under operator's thumb. Special nickel alloy tubes, silver-brazed at head and body. Non-seizing, non-scoring stainless steel valve stems. Mixer designed for perfect gas mixing.

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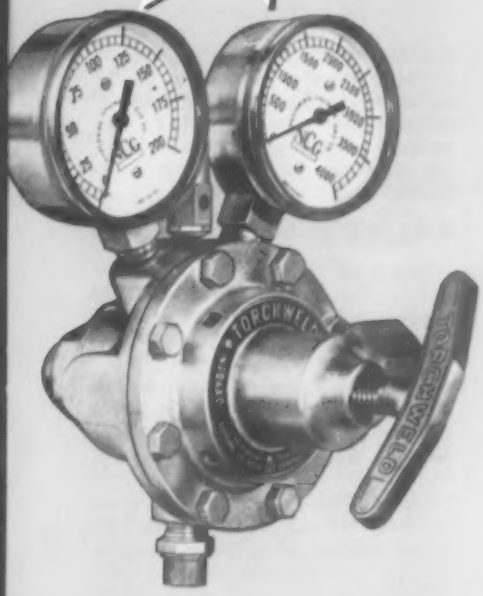

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The best features of both types of regulators—the *dis*advantages of neither . . . that's what you get in the 6500 Series Regulators. That's because of the patented pressure compensating chamber. It maintains desired set pressure *throughout the usable cylinder range!* Yes, here's simple construction, low initial cost, and the precise control of pressures and volumes found elsewhere only in the more expensive two stage regulators.

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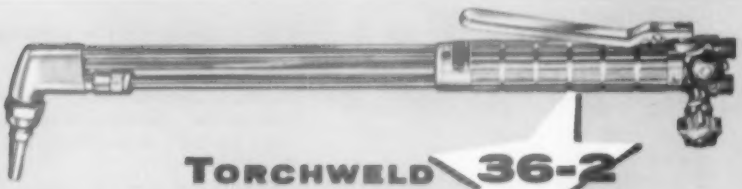
This is the ideal performer for operations of any size or any kind, from small shop to huge mill. Cuts sections up to 16 inches thick.

Pressure-forged, rugged brass valve body; non-seizing stainless steel needle valve stems. Non-warping forged bronze or abuse-resistant nickel alloy heads. Nickel-alloy tubes, set in self-reinforcing triangular formation. Silver-brazed into handle and head. Precision-swaged tip orifices for perfect gas flow and clean, sharp kerfs.

Long control lever, equipped with exclusive *packless* valve. Gives positive smooth control even at lowest rates of flow. Pre-heat gases are blended in tip.



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Top or bottom lever, 75° or 90° forged bronze head. New packless type valve, far outlasts conventional types. Better control and smoother flow of cutting oxygen. Universal type silicon-bronze mixer. Precisely blends preheat gases through entire range of tip sizes. Nickel-alloy tubes, silver-brazed to head and body. Rugged, heavy-duty brass handle, grooved for sure grip and control.

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An efficient, economical soldering, heating and light brazing torch . . . perfect for plumbing, refrigeration, automotive, electrical, maintenance and repair work. Three-way thumb control. Operator turns on and off, adjusts flame and sets pilot light—all with a flip of the thumb. Tips have individual mixers. 6 different sizes for a wide range of work.

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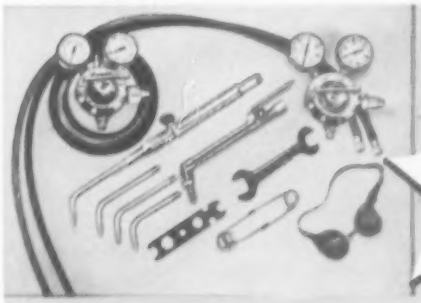

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A wide range of ready-to-use complete outfits for every welding and cutting need in every type of shop or plant. All needed accessories are included. Outfits cost less than the total price of components when bought separately.

NEWS of The Industry

Welding Progress Awards

The James F. Lincoln Arc Welding Foundation of Cleveland, Ohio is offering $20,000 in cash awards for ideas or suggestions that will accelerate progress in arc welding. Residents of the United States or its possessions are invited to submit ideas to the Foundation on any aspect of arc welding that can be used to advance welded design, welding engineering or the general application of the arc welding process. No restrictions are placed on either the nature or the extent of ideas that may be submitted for award. The $20,000 will be distributed in 20 awards with a top award of $5000, others of 4, 3, 2 and 1 thousand dollars and additional smaller awards.

Ideas must be submitted by July 30, 1956.

E. E. Dreese, Chairman of the Foundation describes the offer as an exploratory program to discover ways in which arc welding can continue to progress.

Complete information and Rules are available from The James F. Lincoln Arc Welding Foundation, Cleveland 17, Ohio.

Airco to Expand Gas-Producing Facilities

A 16 million dollar expansion program for 1956 to meet the rapidly increasing demand for its industrial gases is under way by Air Reduction Sales Co., a division of Air Reduction Co., Inc., it has been announced today by J. H. Humberstone, president of that division. This expansion plus the new facilities completed since 1951 bring Airco's total investment increase in the gas-producing field over the six year period to about $50,000,000. It points up the confidence Air Reduction has in the anticipated increased use of industrial gases based on unprecedented growth and development factors, he stated.

Three new producing plants are scheduled for completion this year; at Chicago, Ill.; Alton, Ill., and Calvert City, Ky. Additional producing facilities will also be installed at Butler, Pa., and output will be increased at Riverton, N. J. These plants at Butler, Pa., and Riverton, N. J., are the largest Airco plants for producing liquid and gaseous oxygen, nitrogen, argon, and the rare gases such as neon, krypton and xenon. A portion of the appropriation will go toward expansion of gas-producing facilities in the southwest.

Included as well in this program are additional distribution facilities throughout the country.

NCG Acquires Denver Oxygen Company

Charles J. Haines, president of National Cylinder Gas Co., which for many years has held a minority interest in the Denver Oxygen Co., announces the acquisition of the company and its subsidiary. The Denver Oxygen Co. will operate as a subsidiary of National Cylinder Gas Co.

KSM District Office Opened

KSM Products, Inc., Stud Welding Division, Merchantville, N. J., announces the opening of a new District Office at 1615 Polk Street, San Francisco, Calif.

F. G. Kern has been assigned to this office and represents the company as District Engineer in California. He also supervises Stud Welding Distributors in the states of Washington, Oregon, Nevada, Idaho, Utah, Colorado, Wyoming and Montana.

Spillman Relocates

W. J. Spillman has recently joined the sales force of Long Beach Welders Supply Co., Long Beach, Calif. Mr. Spillman has specialized in welding plants in various parts of the country and for the past six years has engaged in sales of welding equipment and supplies. He is a member of the Long Beach Section of AMERICAN WELDING SOCIETY and will be concentrating his sales efforts in the Harbor Area.

Kacena Celebrates 30th Anniversary

The Kacena Co., Cedar Rapids, Iowa, celebrated their 30th anniversary as a welding distributor with a "Welderama and Industrial Exhibit" at their new store and general office in Cedar Rapids, on March 7th and 8th, 1956.

Featured as a part of the "Welderama" there were demonstrations by more than 20 manufacturers' representatives of the most modern methods of welding, cutting and other metal fabricating processes. Continuous motion picture showings of new products and processes, and displays of the latest equipment gave visitors a further opportunity to see how they can benefit from these recent developments.

Ampco Distributors Appointed

The Weldrod Department of Ampco Metal, Inc., Milwaukee, Wis., has announced the appointment of three, new, exclusive franchised distributors as follows: Miami Welding Supply, Inc., 3016 North Miami Avenue Miami, Florida, Kaminis Welding Supplies, Inc., 3103 4th Avenue, Tampa, Florida, Keenan Welding Supplies Company, Inc., Albany, Georgia.

These distributors will carry a stock of Ampco-Trode, Ampco-Trode AC Phos-Trode and Mang-Trode electrodes in addition to bare filler rods and coiled wire for the automatic and semiautomatic processes.

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

1956 Spring Meeting:
May 7–11, Statler Hotel, Buffalo, N. Y.

Fourth Annual Welding Show
May 9–11, Memorial Auditorium, Buffalo, N. Y.

1956 Fall Meeting:
October 8–12, Cleveland Hotel, Cleveland, Ohio.

IAA Meeting

March 12–14, Fifty-Sixth Annual Convention, Hotel Statler, Los Angeles, Calif.

NWSA Convention

March 19–22, Twelfth Annual Convention, Hotel Roosevelt, New Orleans, La.

Selas Moves to New Site

As part of its continuing expansion and modernization program, Selas Corp. of America has just moved from its Philadelphia site to a new million-dollar plant in the suburbs just north of the city.

Selas develops, designs and manufactures brazing machines and other heat processing equipment for the metals industries.

The new plant is located at the intersection of Limekiln Pike and Dreshertown Road, in Dresher, Pa. The 11-acre site, fourteen miles north of downtown Philadelphia, has been developed to provide fully coordinated facilities for all of the company's activities.

Weldaloy Is New Plant

James A. O'Grady, President of Weldaloy Products Co., recently announced his firm's move from an East Detroit, Mich. location to newly built facilities at 11551 Stephens Drive, Van Dyke, Mich., a Detroit suburb.

The new Weldaloy facilities involve the firm's general offices in one building

and the foundry along with the Weldaloy metallurgical laboratory in another. The foundry is said to be equipped with the latest type of metals melting equipment and automatic accessories.

Weldaloy Products Co. produces alloys to customers' specifications. In addition, this firm manufactures standard and special resistance welding electrodes for portable gun welders, spot, seam, butt, flash, projection, rocker arm welders and machines.

Pocahontas Welding Supply Erects New Building

Pocahontas Welding Supply Co. has moved to their new building located on the outskirts of Bluefield, W. Va., on U.S. Highway 52.

The new building of masonry construction is 50 × 120 feet and includes offices, service and warehouse facilities. A large, well lighted display room extends across the front of the building.

The new location provides ample parking space for convenience of customers. Loading docks in the rear accommodate trucks and trailers, one of which is inside for loading or unloading during bad weather.

Walter P. Sowers, president, and J. L. Kirk, Jr., vice-president, started Pocahontas Welding Supply Co. in 1947.

Tube Turns Appoints Morris

L. J. (Lew) Morris has been appointed assistant district manager at Pittsburgh, succeeding W. C. (Bill) Robinson, it is announced by John G. Seiler, executive vice-president of Tube Turns, Louisville, Ky. Mr. Robinson was recently made an assistant sales manager and is engaged in sales promotional programs in the company's Eastern Division.

Mr. Morris was born in North Bergen, N. J. He became a member of the Pittsburgh sales staff in 1949.

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TRIPL-FLINT* SAFETY LIGHTER!
• Exclusive! Guard eliminates snagged pocket linings!
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PERSONNEL

Roberts Wins First Prize

Stanley I. Roberts, a welding engineer in the Shop Superintendent's Office, walked off with the $100 Savings Bond which was first prize in the recent contest to find suggested methods of improving the efficiency at San Francisco Naval Shipyard.

Stanley I. Roberts

The contest was sponsored by the SFNS Employees' Association. President Robert D. Cherrigan handed out the prizes.

The second prize of a $50 Bond went to Albert J. Belair, an analyst and scheduler in Shop 26, and the third prize was snared by John D. Mitchell, Benny Sugg Investigator in Shop 11.

Several other entries were received containing many good ideas and the contest judges had a hard time deciding on the top three.

Mr. Roberts is a member of the AMERICAN WELDING SOCIETY.

John Caluwaert Elected Vice-President

John Caluwaert has been elected vice-president of Industrial Air Products of the South, and Levon Josephian has been appointed general plant superintendent of Industrial Air's plants, it was announced recently by Gilbert Schnitzer, President.

Mr. Caluwaert was manager of Industrial Air of the South, having previously served as assistant sales manager of the Industrial Air Products Co., Portland, Oregon for seven years. He is a member of the AMERICAN WELDING SOCIETY.

Mr. Josephian has had 20 years of experience in the oxygen industry, having formerly been employed by the Pacific Oxygen Co., Oakland, Calif. He will be in complete charge of all of Industrial Air Products plants.

Schultz Joins Federal

The Federal Machine and Welder Co., Warren, Ohio, announces the association of Harry L. Schultz with its Warco Press Sales Engineering Department.

Mr. Schultz has been associated with the manufacture, design and application of presses for twenty years. He is a graduate mechanical engineer of Case Institute of Technology, Cleveland. Just prior to coming to Federal, he was employed as Chief Engineer by The Cleveland Punch and Shear Works, Cleveland, Ohio.

William T. Wilbur

Wilbur Named by Progressive Welder

Progressive Welder Sales Co., Pontiac, Michigan, announces the appointment of William T. Wilbur as Chief Application Engineer. Mr. Wilbur brings to his new position an experience of over 16 years as Application Engineer and Head Designer in charge of resistance welding programs for large users.

Until recently, Mr. Wilbur had his own special machine and product design company which handled resistance welding machine design for several large welding manufacturers.

In his new position, Mr. Wilbur will be responsible for the design of all special application, resistance welding equipment. He is a member of the AMERICAN WELDING SOCIETY.

Ballard Joins Goodrich

Goodrich Welding Equipment Corp. of Hudsonville, Michigan announces the appointment of Robert L. Ballard as senior designer and customer liaison Engineer.

Mr. Ballard comes to Goodrich Welding Equipment from the Studebaker-Packard Corp. where he was supervisor of body process and welding engineering.

Mr. Ballard was formerly affiliated with the Resistance Welder Corp. and Progressive Welder Sales Co. as a senior designer and customer liaison engineer.

Taylor Elected President of Harris Calorific

Clarence Minor Taylor, one-time executive vice-president of Lincoln Electric Co. has been elected president of the Harris Calorific Co. in Cleveland, succeeding the late Lorn Campbell, Jr.

Clarence Minor Taylor

Taylor's association with the gas welding equipment manufacturer has been that of a director, an association he continues.

Taylor started at Lincoln Electric in 1916 as a shop apprentice. By 1927 he had achieved election to the Lincoln board. He was appointed Lincoln sales vice-president in 1928 and executive vice-president in 1946.

His civic and business associations include membership in the Cleveland Chamber of Commerce and directorship in Cleveland Hardware & Forging Co.,

John R. Milligan

Ferro Corp., Gregory Industries, S. K. Wellman Co. and the Society for Savings Bank. He is also a trustee of Fenn College, Western Reserve University, Cleveland Clinic and the McGregor Home for the Aged.

At the same time, John R. Milligan has been appointed vice-president and all the administrative functions of the company will be placed under his direction. Mr. Milligan is a Lehigh University graduate and was with B. F. Goodrich Co. at Akron for 12 years doing Trade Coordination work. He has been with the Harris Calorific Co. for 20 years and was Secretary and Treasurer for many years.

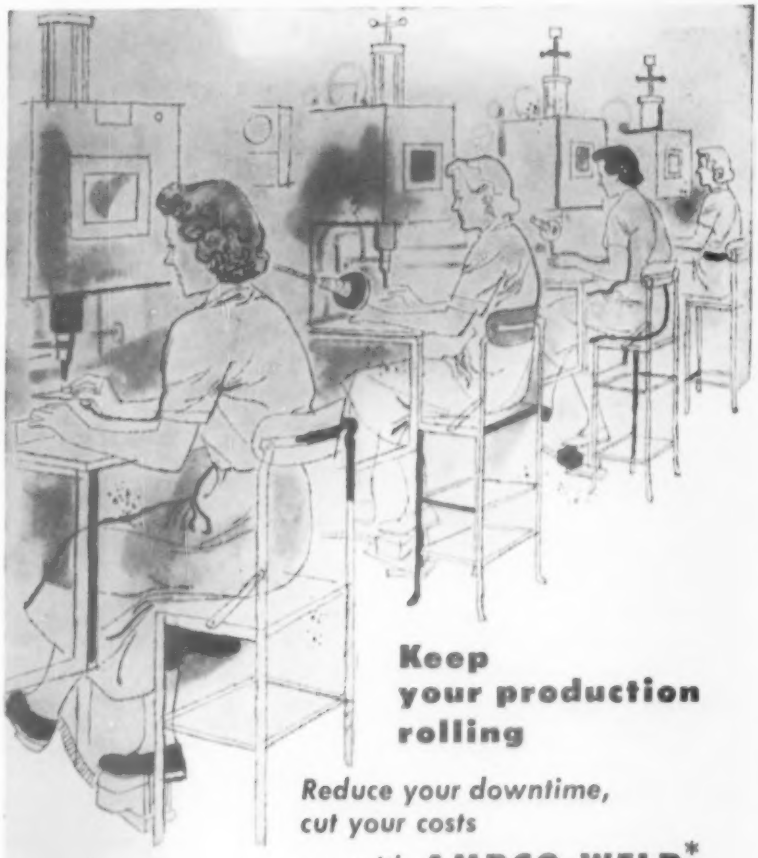
Both Mr. Taylor and Mr. Milligan are members of the AMERICAN WELDING SOCIETY.

Appointed Field Representative by Alloy Rods

William Troy, Jr., of Baltimore, Md. has joined the sales staff of Alloy Rods

William Troy, Jr.

Co. as Field Representative. His territory will be Maryland and South Central Pa., and he will make his headquarters in Baltimore.



Keep your production rolling

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. . . with* AMPCO-WELD* *resistance-welding products

Strict laboratory control over all manufacturing processes, unique with Ampco Metal, pays off for you in consistently uniform, quality products. You receive extra bonuses with AMPCO-WELD that keep your production rolling. Extra bonuses such as consistently high electrical conductivity combined with strength and toughness beyond the limits usually available. These are important characteristics which reduce sticking to the work, increase resistance to mushrooming and wear at high temperatures.

AMPCO-WELD seam welding wheels — "off-the-shelf" shipment of rough forgings or finished blanks. Rapid delivery of wheels machined to your specifications.

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AMPCO-WELD holders — delivery from stock of straight, offset, or universal ejector types. Offset and universal holders have interchangeable sockets for No. 1 and 2 tapers.

Don't put up with downtime — order AMPCO-WELD products today. They always meet or exceed RWMA specifications. Contact your local AMPCO-WELD Distributor or write for latest literature. SW-47

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NEW LITERATURE

Nickel Alloy Pressure Vessels

The Welding Research Council has just issued Bulletin No. 24 covering characteristics of nickel and high-nickel alloys for pressure vessel use. The report discusses in detail the analysis, physical and mechanical properties, method of determining ASME code design stresses, embrittlement by sulfur and lead, hot and cold forming, thermal treatments, cleaning, pickling, welding, brazing, joining of dissimilar metals and inspection. A discussion of the special characteristics of age hardenable alloys is also included.

This Bulletin consists of twenty-seven pages and is priced at $1.00 per copy (limited edition). Copies may be ordered through the AMERICAN WELDING SOCIETY, 33 West 39 St., New York 18, N. Y.

Radiation-Control Regulations

Regulation of Radiation Exposure by Legislative Means, National Bureau of Standards Handbook 61, 6 tables, 60 pages, 25 cents. (Order from Government Printing Office, Washington 25, D. C.).

Prompted by repeated inquiries from individuals and groups seeking guidance and information, this handbook presents the problem of radiation in relation to its possible control by State or municipal authorities.

This report is based on studies of radiation control conducted by the National Committee on Radiation Protection under NBS sponsorship. The material it contains will provide a convenient and suitable basis for the development of uniform radiation-control regulations that can be used by States where the need for regulation may be felt.

Elevated Temperature Properties of Carbon Steels (ASTM Special Technical Publication No. 180) is the fourth publication in a current series prepared under the auspices of the ASTM-ASME Joint Committee on the Effect of Temperature on the Elevated Temperature Properties of Metals.

This "carbon steel compilation" includes data for tensile and yield strength, elongation and reduction of area, stresses for creep rates of 0.0001 and 0.00001 per cent per hour and rupture strengths for 100, 1000, 10,000 and 100,000 hours.

The steels covered are killed carbon steel (0.18 to 0.24 C), ASTM A201 Grade B plant steel (0.24 C max), ASTM A106 Grade B pipe steel (0.30 C max), killed carbon steel (0.27 to 0.58 C), aluminum killed steel, open steel (rimmed or capped), and miscellaneous carbon steels (limited data available).

The properties are given in graphical form and supplemented by copies of original data sheets from those contributing the data.

Copies of this 68 page book can be obtained from ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa., at $3.75 per copy.

Welding of Tubing

The Tubular Products Division of The Babcock & Wilcox Co. has issued Technical Data Card 155A. This card summarizes the various recommendations for joining, by arc welding procedures, various tubing steels. In addition to indicating the proper electrodes to use, it provides information about preheating and postwelding heat treatments. Fabricators and others who have occasion to weld stainless steels and chromium molybdenum alloy steels in tubing and other forms will find this card valuable as a reference. Copies of TDC-155A can be obtained, free of charge, upon request to the sales offices of the company at Beaver Falls, Pa.

Accident Prevention Manual

The National Safety Council has published a new and greatly expanded edition of its Accident Prevention Manual for Industrial Operations.

Designed as the basic text for the safety man's shelf, this 3rd Edition of the Manual includes all the information needed to organize a comprehensive safety program and keep it going. In addition there are many informative chapters covering the specific types of hazards found in most industrial operations.

The Manual is a 1341-page encyclopedia of safety that entailed more than three years of research, writing and revision by Council engineers and other safety specialists from industry, government and other groups. It contains data on every aspect of industrial accident prevention.

The Accident Prevention Manual is priced at $13.50 and may be purchased from the National Safety Council, 425 N. Michigan Ave., Chicago 11, Ill. For those desiring more complete information on the subject matter covered in the Manual, a descriptive folder will be sent on request to the Council.

Metallurgy at Stanford

Metallurgy, a field to which welding is closely related, often leads to exciting careers, and there is every indication that job opportunities will continue to be abundant in the coming years. However, there appears to be many high school students interested in careers in science or engineering who do not have the slightest idea of what metallurgy is.

As a partial answer to this need, the School of Mineral Sciences, Stanford University, Stanford, Calif., has prepared a short but informative booklet on metallurgy and are distributing it to high school science teachers, vocational advisers, and to any one interested in learning about careers in the various branches of science and engineering.

Stanford University will be glad to mail one of these booklets to any interested party upon direct request.

Bronze Filler Metal

Ampco Metal, Inc. has released a new, revised Bulletin W-17 entitled "Welding with Ampco Bronze Electrodes-Filler Rod-Wire."

Included in this bulletin is up-to-date technical information and data relative to arc welding with bronze electrodes, filler rods and wire products. Specific sections describe the new Phos-Trode C, Mang-Trode and Ampco-Trode 46 electrodes, welding techniques, welding processes, recommended welding currents, welding procedures, weldability chart, etc.

The data contained in W-17 is intended for welding engineers, design engineers, welding supervisors and welding operators as a reference on welding with bronze electrodes and filler rods. Send for a free copy from Ampco Metal, Inc., 1745 South 38 St., Milwaukee 46, Wis.

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NEW PRODUCTS

Electrode Holders

The new Wagner HI-AMP electrode holder made by Wagner Manufacturing Co. of Jackson, Mo. introduces two much needed improvements in the electrode holder field, according to the manufacturer.

1. The wrap-around fiber glass tip insulator (interchangeable) increases electrical insulation and heat resistance 30% more than any other make.
2. Brilliant red and yellow fiber glass colors insures identification of holder anywhere in plant—a valuable safety feature. All models for 1956 include these added advantages.

For additional details, write directly to the company.

Iron-Powder Electrode

A new low-hydrogen, iron-powder, E7016 classification, welding electrode has recently been added to the line of electrodes manufactured by The McKay, Co., Pittsburgh, Pa.

This new electrode is claimed to combine the outstanding operating characteristics and versatility of low-hydrogen electrodes with the increased deposition rate of iron-powder grades. This rate is as much as 35% more than those obtainable with conventional low-hydrogen coatings.

A technical bulletin containing pertinent information for the McKay E-716IP is available on request. Write to The McKay Co., 303 McKay Building, Pittsburgh 22, Pa.

Tungsten Electrode

A new 2% thoriated tungsten electrode for tungsten inert-gas welding has been introduced by the Tungsten and Chemical Division of Sylvania Electric Products Inc., 1740 Brodway, New York 19, N. Y.

In specific applications, the new 2% thoriated electrode is superior to 1% thoriated electrodes, giving easier arc starting, more stable arc, higher current capacity, longer life, and increased resistance to weld pool contamination, the Sylvania announcement said.

Sylvania produces a complete line of tungsten electrodes, including Puretung, Zirtung, Thoriated, and the new 2% Thoriated.

Low-Hydrogen Electrode

Atom Arc 7016 Mo, for welding carbon-moly steels, has been added to the Alloy Rods Co. line of iron-powder low-hydrogen electrodes. This new electrode deposits a weld metal containing 50% molybdenum and was added to the line to meet a demand for an electrode for carbon-molybdenum weldments. Atom Arc 7016 Mo has a tensile strength of 79,000 psi., with an elongation of 31%, 2-in. scale.

For additional information, data sheets giving complete details and welding instructions are available from the company. Write to Alloy Rods Co., Lincoln Highway West, York, Pa.

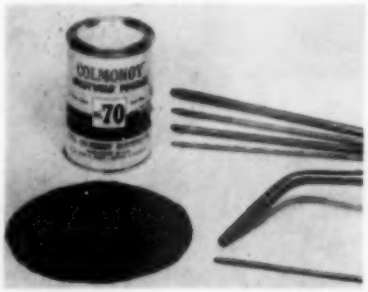
All-Position Electrode

The Lincoln Electric Co. of Cleveland, Ohio, announces an all-position E6013 electrode, Fleetweld 37, for a-c or d-c current, designed especially for ease of operation. Its features are described as being particularly useful either in welding sheet metal where burn-through, sticking and poor fit-up may be problems; or when using low open-circuit voltage welding machines, such as are generally used on farms or in small shops, or for steel plate fabricating where an all-position, easy operating electrode is desired. Fleetweld 37 is claimed to have excellent arc stability.

The electrode is available in 1/8, 5/32 and 3/16-in. sizes, packed in 50-pound packages.

Hard-Facing Alloy

A new nickel-chromium-boron-tungsten hard-facing material which provides parts exposed to extreme conditions of vibration and/or heat with a wearproof, corrosion-resistant surface



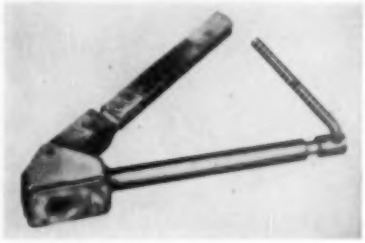
is now available from Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich. Named Colmonoy No. 70, the new alloy has a high tungsten content.

Colmonoy No. 70 is available as a powder for application by Spray-welding or as welding rod in 3/16, 1/4, 5/16 and 3/8-in. diam for application with an oxyacetylene torch flame. It is also available as castings.

According to the manufacturer, the new alloy possesses excellent corrosion, heat and abrasion resistance. It is claimed to produce a surface whose hardness ranges from 50 to 55 Rockwell C; specific gravity is 8.5; melting point is approximately 2000° F.

Tip Puller

A tool for removing spot welder tips more efficiently, called the Ejecto Tip Puller, was announced recently by the Miller Electric Manufacturing Co., Inc., Appleton, Wis.



This device tightens over the tip by means of a small high leverage crank. Easy pressure on the handles then withdraws the tip quickly and without damage to either tip or horn.

Descriptive literature is available by writing directly to manufacturer.

Brazing Rod

Ampco-Brāz No. 3 is a manganese bronze filler rod conforming to ASTM B259–52T AES 5.7, Class R Cu Zn B, ASTM B260-52T AWS 5.8, Class B Cu Zn 3, Navy 46-R-1b, Type A; 1/3/33 and Federal QQ-R-571a, Type 1, Class FS-R Cu Zn-Z (Amend. 1–9/15/54).

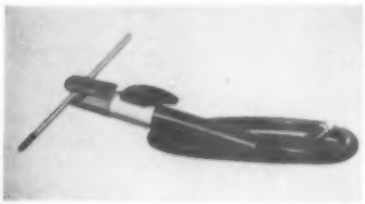
According to manufacturer, this type of filler rod has good tinning action when used with ordinary brazing fluxes; flows easily; melting point is relatively

low (1600° F); and the deposit has high strength combined with good ductility. Ampco-Brăz No. 3 is claimed to be a good all-purpose, general maintenance rod for brazing cast iron, repairing pistons, gear teeth, shafts, etc.

For further details write to Ampco Metal, Inc., 1745 South 38th St., Milwaukee 46, Wis.

Cutting and Gouging Torch

The new Model G-5 Arcair cutting and gouging torch is especially designed for heavy duty work and longer service life. It features new, impact-resistant moulded jaw insulators, and a new silicone glass laminate sleeve to protect the upper end of the handle from the heat. This new torch will take up to $^5/_{32}$-in.



diam electrodes, and delivers almost twice as much air as the previous G-3 model.

As with all Arcair torches, the new G-5 operates from an ordinary d-c welding machine and a compressed air line. This model also features a rotating nozzle that permits changing electrode angle to suit the job, but always maintains air jet in perfect alignment. Air and current are brought to the torch through a concentric cable, permitting great flexibility and ease of handling. Depth of cut and amount of metal removed can be closely controlled by the operator.

For complete information on the new Model G-5 torch, address inquiries to Arcair Co., 423 South Mt. Pleasant Street, Lancaster, Ohio.

Convertible Ignitrons

Three types of "convertible" ignitrons for use with or without temperature control, thus eliminating the necessity of double-stocking tube types, have been added to the General Electric line of welding and power conversion tubes.

The new G-E ignitrons are the GL-5551-A, GL-5552-A, and GL-5553-B (sizes B, C and D, respectively), and they differ from their prototypes in the addition of a slotted copper plate on the envelope to which a thermostat can be clipped. The copper plate is in thermal contact with the inner cylinder of the tube and maintains substantially the same temperature. The thermostat is clipped to the copper plate with a bracket held by spring clips.

Full details may be had by writing to General Electric Co., Schenectady 5, N. Y.

Toggle Clamps

Two new models have recently been added to the line of Caddy Toggle Clamps manufactured by Erico Products, Inc. According to the manufacturer, the VQ-1 and the VQ-2 have a unique design of linkage that provides maximum bar travel with minimum handle movement. The VQ-1 is rated at 1000 lb. vertical clamping pressure while the VQ-2 is rated at 2000 lb. Designed primarily for the aircraft industry, the VQ series has found wide-

AND NOW
2 MORE FIRSTS
by Wagner
HI-AMP
ELECTRODE HOLDERS

Wrap around Plastic Tip Insulation for maximum electrical insulation and heat resistance — 30% more than any other make.

Brilliant Red and Yellow Plastic Colors insures identification of Holder anywhere in plant—Valuable Safety Feature.

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Weld with Wagner

for money-saving metal removal on
STAINLESS STEEL...

Arcair® TORCH

● ON STAINLESS STEEL, the Arcair torch has proven itself as a tool unsurpassed for quick, money-saving metal removel in a wide variety of applications. Whether for cutting, gouging, beveling or grooving—the Arcair torch is ideal on Stainless, as these actual case history applications prove . . . cutting through $^3/_8$" plate on a fabrication operation, *in one-half the time of former method* . . . cutting through tank liners *without damaging the tank itself* . . . cleaning roots of welds in Stainless tanks, *saving 60% in time over old method* . . . removing risers on small Stainless castings and repairing casting defects, *five times faster* than the old grinding method . . . and cutting inlets in tanks and pipes quickly and easily, *an almost impossible job to do accurately by other methods!*

SIMPLE TO OPERATE, the patented Arcair process is based on the gouging, cutting, grooving or beveling of metal by melting it with an electric arc and blowing away the melted metal with a high velocity jet of compressed air.

IF YOU WORK ON, OR PROCESS stainless steel, you just can't afford not to have the money saving advantages of the unique Arcair torch. WRITE FOR COMPLETE DETAILS TODAY!

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Write for your FREE copy of Arcair's new "CASE HISTORY BOOK". See positive proof of Arcair money-saving performance in countless industries!

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For fast, horizontal fillet and down hand welding. Rutile type.

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For fast, all position welding. Rutile type.

For CHAMPION RESULTS
Choose these
IRON POWDER
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■ Champion Speedemon iron powder electrodes are carefully compounded to insure uniform quality weld deposits. These electrodes offer very high deposition rates with minimum spatter loss and extremely easy slag removal. They offer extreme ease of handling. *Full information is available upon letterhead request to Dept. A*

NO. 716

For fast, high quality any position welds on hard to weld steels. Low hydrogen type.

NO. 716-MO

For fast, all position welding on 70,000 P.S.I. steels. Low hydrogen .5% Moly type.

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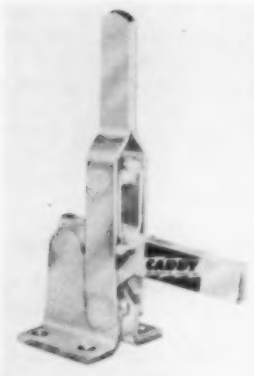
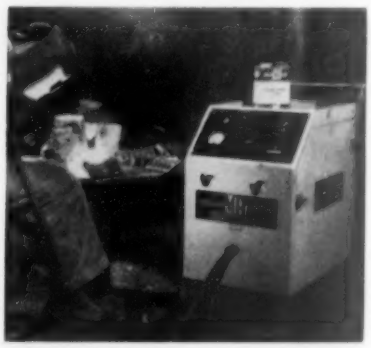


spread use in all fields. Complete information including full size templates are available on request from Erico Products, Inc., 2070 E. 61st Place, Cleveland 3, Ohio.

Semi-Automatic Welder

A portable welding machine designed specifically for manganese steel and hardfacing work on irregularly-shaped parts is being made available to industry after two years' rugged field testing in construction, the Amsco Division of American Brake Shoe Co. has announced.



As designers and manufacturers of the New "MF" Welder, Amsco said that production models of the equipment are being used in servicing and repairing equipment in construction, mining, excavating, dredging highway building, railroad operation and industrial maintenance.

Welding wire is fed automatically through the flexible cable at a rate governed by the size of the welding arc, and flux is fed through cone-shaped hopper above the weld contact. Flux, which is available in several compositions to give varying welds adheres magnetically to the weld wire.

The MF Welder, mounted on large industrial casters and displacing no more space than an average floor model television set, is designed to plug into conventional a-c or d-c welding units

by a single cable. The MF operates on a current range of about 150 to 450 amp.

For complete details, write to Amsco Division, American Brake Shoe Co., Chicago Heights, Ill.

Submerged-Arc Welders

The two welding machines shown in the accompanying photograph, designed and made by Alliance Machine Co. of Alliance, Ohio, to reduce welding time on large girders it fabricates for the steel industry, are reported to have

cut welding time 70%. They weld two web to cover plate joints simultaneously with the girder positioned flat on its side. The units, mounting Lincoln Electric LAF submerged-arc welding heads, are self-propelled and ride on the girder web guided by the edge of the flange. Controls and flux recovery equipment are also mounted on the unit. Operation is completely automatic. At the end of the weld, the units run off onto an adjustable table which then carries them to the next welding job. In addition to welding time reduction, it is claimed that the units have also effected savings in handling and cleaning time. Their portability and flexibility permit them to be used on many different fabricating jobs.

Remanufactured Ignitrons

Remanufactured ignitrons which carry a new tube warranty and bring a considerable saving to the user are now available through General Electric distributors, according to a recent announcement by the Company's Tube Department.

The remanufacturing plan covers types GL-5551, GL-5552, and GL-5553A (sizes B, C and D, respectively), which are used extensively in welding and other power conversion applications. Using remanufactured tubes for replacement can bring savings of nearly 30% per tube, the Company estimates, with dollar savings varying from $17.90 for one tube to $6300 for 100 tubes.

In remanufacturing these ignitrons, General Electric explains that it maintains the same quality control conditions that prevail in making new ignitrons.

For additional details, write to General Electric Co., Schenectady 5, N. Y.

D-C Rectifier Welders

Miller Electric Mfg. Co., Inc., Appleton, Wis., has announced a newly designed d-c rectifier-type welder, horizontal, rather than upright in design. These units, called the SRH Series, were developed to conserve floor space and to facilitate stacking and paralleling.

The SRH welders have a single-current range and are available in three models with 60% duty cycle ratings of 200, 300 and 400 amps.

The case is of weatherproof construction, making it ideal for outdoor use, according to the manufacturer.

AT THE FRONTIERS OF PROGRESS YOU'LL FIND

FOR WELDING AND CUTTING...

IN THE RED DRUM

HIGHEST QUALITY

DUST-FREE

AN AIR REDUCTION PRODUCT

NATIONAL CARBIDE

Write for the name and address of the NATIONAL CARBIDE supplier nearest you.

National Carbide Company

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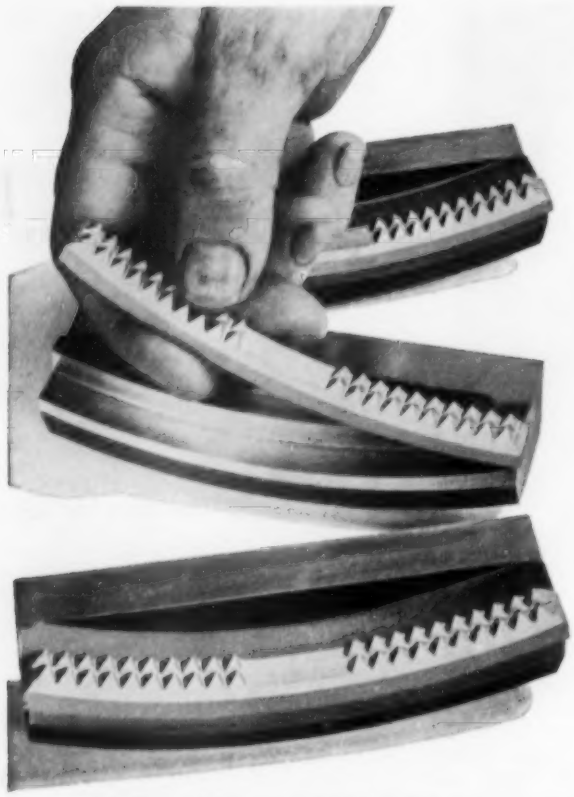

Colmonoy Castings INCREASE Chuck Jaw Life

Castings made of Colmonoy hard-facing alloys are being built into many products at points of extreme wear. They prolong the life of such products many times over.

The chuck jaws shown above are designed using castings of Colmonoy No. 5, silver brazed in place. The benefits: ten weeks of service instead of three, and then easy replacement of the worn insert instead of rebuilding the jaw itself.

Investigate Colmonoy castings. Provide your products (and production equipment) with two, three, or even thirty times longer life, and at modest cost.

Submit part drawings and a description of the wear encountered for a specific recommendation. Request Hard-Facing Manual No. 79.

HARD-FACING ALLOYS

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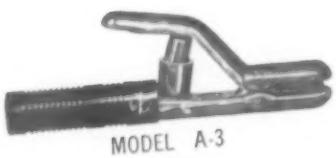
Duty-Cycle Rated for Top Production

JACKSON
Insulated Copper Alloy Holders

MODEL AW-C

MODEL A-1



MODEL A-3

MODEL A-3S

QUALITY JACKSON PRODUCTS

In today's competitive race for stepped-up production, we see new welding machines and new electrodes coming on the market, all designed to do the work easier and faster.

Therefore, in choosing the right electrode holder for a job, don't think of *rod size* alone. We must equally consider *amperage* and *cable size*, and today, more than ever, the required *number of electrodes per hour*. These four factors combined establish the *duty cycle*, that is the percentage of actual arc-time in any ten-minute period of work.

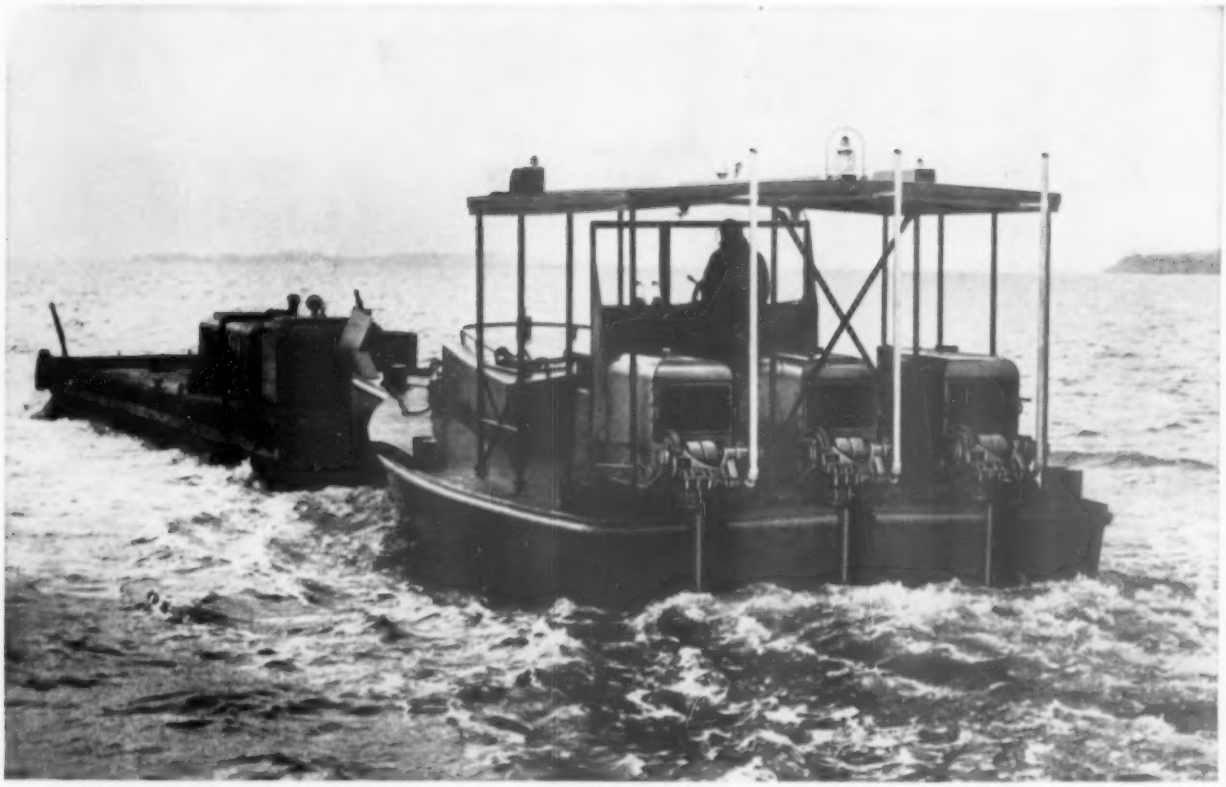
The following table shows the duty cycles possible with the various *Jackson Insulated Copper Alloy Holders*, based on using the electrodes and cable sizes as indicated.

Holder Class	Model Number	Electrode Size	Amperage	Cable Size	Duty Cycle
SMALL	AW-C	7/32"	250 300	1 1/0	50%
MEDIUM	A-1	1/4"	300 350	1/0 2/0	50%
LARGE	A-3	3/8"	375 450	2/0 3/0	65%
HEAVY-DUTY	A-3S	3/8"	500	4/0	80%

This table will help you in making the right selection from these Jackson copper alloy holders. Using a superior 98% copper alloy heat treated for greater strength, hardness and conductivity, these holders permit highest duty cycles with ample margin of safety.

Sold through Distributors and Dealers throughout the United States and Canada

JACKSON
PRODUCTS, INC.
WARREN · MICHIGAN



The Harbormaster, is a king-size power unit designed for rough use aboard barges, dredges and work boats. An Airco Oxygraph is a key production tool used to quickly and economically flame cut over 25 of its component parts from heavy steel. Airco electrodes—the Easyarc 12—are depended upon for the utmost in strength and welding speed.

Airco Electrodes & Cutting Machines

satisfy design and strength needs for unique outboard engine

The Mathewson Machine Works Inc., have been manufacturers of marine equipment since 1885. They find in building the Harbormaster that the extensive use of Airco electrodes, cutting equipment and industrial gases combine to provide them with the greatest degree of production flexibility and the widest margin of economy.

From planning to production you can rely on assistance—and completely unbiased recommendations—from Airco Technical men. For Airco is the leading supplier—manufacturer of all kinds and every type of welding and flame cutting processes, their controls, supplies and accessories.

Write to Airco for free literature on electrodes, cutting apparatus, and cutting machines.

WELDING SHOW

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